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## CHEMICAL SECTION.

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### THE CLARIFICATION OF RIVER WATERS.


BY ALLEN HAZEN.


It is an old saying that mortals care more for their worldly goods than for their spiritual welfare. It is equally true that people care more for the appearance of the water which they drink than they do for its healthfulness.

One reason for this may be that appearance is, in a measure, an indication of quality, and an indication which everyone can apply for himself; and there may be an element of vanity which leads us to put the qualities which we can note for ourselves above those which we cannot see, and which we only know about through the reports of others, of the exact value of which we allow ourselves to be a little skeptical. At any rate, clear water is only second in importance to wholesome water, and is worth all the effort that is necessary to secure it.

The ideal water in appearance is distilled water, which is perfectly clear and limpid, and has a slight blue color. When other waters are compared with it, the divergences in color from the color of distilled water are measured, and not the absolute colors of the waters. Many spring waters and filtered waters are indistinguishable in appearance from distilled water.

Public water supplies taken from rivers contain two substances or classes of substances which injure their appearance, namely, peaty coloring matters and mud. Waters discolored by peaty matters are most common in New England and in certain parts of the Northwest, while muddy waters are found almost everywhere, but of different degrees of muddiness, according to the physical conditions of the water-sheds from which they are obtained.

Muddy waters are often spoken of as colored waters, and in a sense this is correct where the mud consists of clays or other materials having distinct colors; but it is more convenient to classify impurities of this kind as turbidities only, and to limit the term colored waters to those waters containing in solution vegetable matters which color them.

The removal of either color or turbidity may be called clarification.

Colored waters are usually drawn from water-sheds where the underlying rock is hard and does not rapidly disintegrate, and where the soils are firm and sandy; and especially from swamps. The water here comes in contact with peat or muck, which colors it, but is so firm as not to be washed by flood-flows, and so does not cause turbidity.

Large parts of the United States have for rock foundations shales or other soft materials which readily disintegrate when exposed, and which form clayey soils readily washed by hard rains. Waters from such water-sheds are generally turbid and very rarely colored. In fact, a water carrying much clay in suspension is usually found colorless when the clay is removed, even if it were originally colored. It thus happens that waters which are colored and turbid at the same time hardly exist in nature.

Color-producing matters and turbidity-producing matters are different in their natures, and the methods which must be adopted to remove them are different. I shall speak to you to-night only of the removal of turbidity.

But first let us consider how water becomes turbid. Consider, if you please, a plowed field of clayey soil, or such a field upon which crops are growing. If it has not rained for some days, and the surface-soil is comparatively dry, the first rain that falls upon it is absorbed by the pores of the soil until they are filled. If the rain is not heavy, but little runs off over the surface. If, however, the rain continues rapidly after the surface-soil is saturated, the excess runs off over the surface to the nearest water-course. The impact of the rain-drops upon the soil loosens its particles, and the water flowing off carries some of them in suspension, and the water is said to be muddy.

The particles carried off in this way are extremely small. Mr. George W. Fuller, in his report upon water purification at Louisville, estimates that many of them are not more than $\frac{1}{100000}$ of an inch in diameter, or not more than $\frac{1}{10}$ as large as the common water bacteria. These particles, and larger ones, may sometimes be present in water to such an extent as to form more than $\frac{1}{1000}$ of its weight.

The amount of mud in a water is often expressed as the proportion of suspended matters referred to the weight of the water. This method of statement does not altogether meet with our requirements, because it fails to take into account the different sizes of the particles which are carried in suspension by different waters, and at different times. The Merrimac River in a great flood may carry 1 part in 1,000 of fine sand in suspension, and still it could hardly be called muddy; while another stream carrying only a fraction of this amount of fine clay would be extremely muddy. Further, an accurate determination of suspended matters is a somewhat troublesome and tedious operation, and cannot be undertaken as frequently as is necessary for an adequate study of the mud question.

Turbidity is principally important as it affects the appearance of water, and it would seem that optical rather than

gravimetric methods should be used for its determination. The literature of engineering contains descriptions of numerous appliances, more or less elaborate, for measuring the obstruction to light of given depths of waters. Some of these methods, theoretically most perfect, are too complicated for general use.

Some years ago, while making experiments at Lawrence for the Massachusetts State Board of Health, I found it necessary to have a method of expressing the turbidities of various waters, and I adopted the very simple device of sticking a pin into a stick and pushing it down into the water under examination as far as the pin could be seen and measuring the depth. Afterward a platinum wire, 0·04 of an inch in diameter, was substituted for the pin, and the stick was graduated so that the turbidities could be read off directly. The figures on the stick are inversely proportional to their distances from the wire. When the wire can be seen 1 inch below the surface, the turbidity is 1·00; when the wire can be seen 2 inches, the turbidity is 0·50; when it can be seen 10 inches, the turbidity is 0·10, etc. This scale is much more convenient than a scale showing only the depth at which the wire can be seen; and within certain limits the figures obtained by it are directly proportional to the amount of the elements which obstruct light in the water. Thus, if a water having a turbidity of 1·00 is mixed with an equal volume of clear water, the mixture will have a turbidity of 0·50. This procedure is used for the determination of turbidities so great that they cannot be conveniently read by direct observation.

For the greatest accuracy it is necessary that the observations should be taken in the open air and not under a roof. They should preferably be made in the middle of the day, when the light is strongest, and in case the sun is shining the wire must be kept in shadow and not in direct sunlight.

The method thus developed has been used in a number of cases with most satisfactory results. If it lacks something in theoretical accuracy as compared with more elaborate methods, it more than makes up for it by its simplicity and general adaptability to all sorts of conditions. Reliable

observations can be taken by people who would be entirely incompetent to use more elaborate apparatus, and its application is thereby greatly extended.

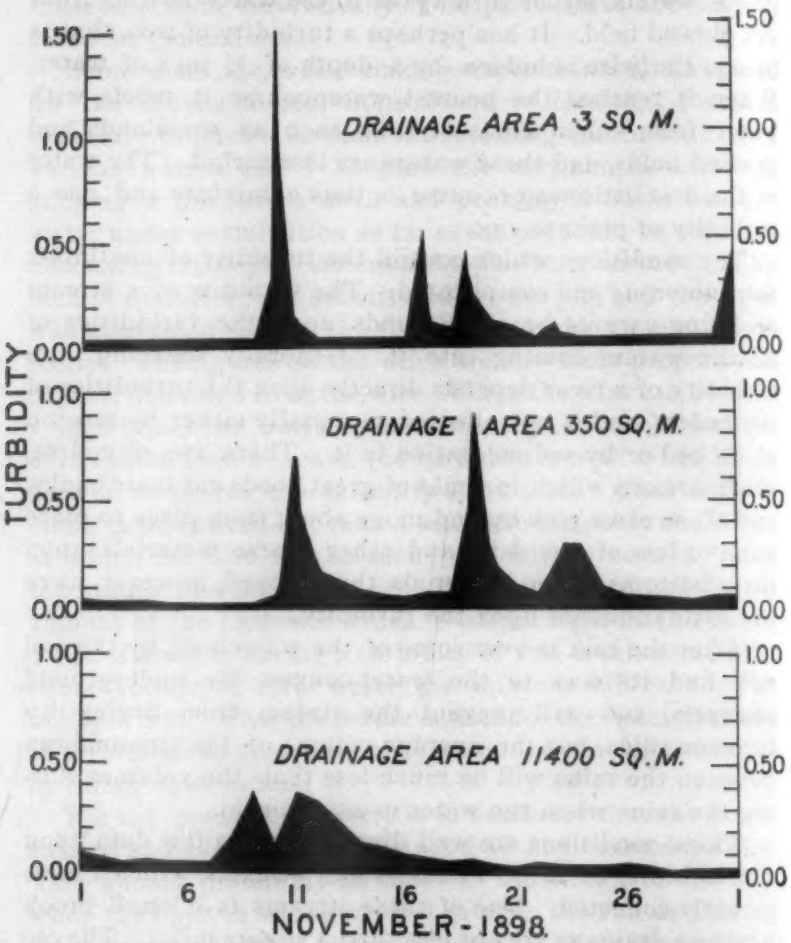
Having now a scale with which to measure the turbidities of waters, let us turn again to the water flowing from our plowed field. It has perhaps a turbidity of 2·00, that is to say, the wire is hidden by a depth of ½ inch of water. When it reaches the nearest water-course it meets with water from other kinds of land, such as woodlands and grassed fields, and these waters are less turbid. The water in the first little water-course is thus a mixture and has a turbidity of perhaps 1·00.

The conditions which control the turbidity of any brook are numerous and complicated. The turbidity of a stream receiving various brooks depends upon the turbidities of all the waters coming into it. Generally speaking, the turbidity of a river depends directly upon the turbidities of its feeders, and is not affected materially either by erosion of its bed or by sedimentation in it. There are, of course, some streams which in times of great floods cut their banks, and all streams pick up and move about from place to place more or less of the sand and other coarse materials upon their bottoms. The materials thus moved, however, have but little influence upon the turbidity.

After the rain is over some of the water held by the soil will find its way to the water-courses by underground channels, and will prevent the stream from drying up between rains, but the average volume of the stream-flows between the rains will be much less than the volumes during the rains when the water is most turbid.

These conditions are well illustrated by a few data upon the turbidity of three Pennsylvania streams, which I have recently collected. One of these streams is a small brook having a drainage area of less than 3 square miles. The observations extend over a period of forty-seven days. During this time there were five floods, or an average of one flood in ten days. The duration of floods was less than twenty-four hours in each case. Selecting the days when the turbidity was highest, to the number of one-tenth of the whole number

of days, the sum of the turbidities for these days was 67 per cent. of the aggregate turbidities for the whole period. That is to say, 67 per cent. of the whole amount of mud




Turbidities of three Pennsylvania streams of different sizes during November, 1898.

was in the water of only a tenth of the days, the other nine-tenths of the days containing only 33 per cent. of the whole amount of turbidity. The average turbidity of the water

for the flood days was 18 times as great as the average turbidity for the remaining days.

The next stream is a considerable creek having a drainage area of 350 square miles. The observations extended over 117 days, during which time there were seven floods, or an average of one flood in nineteen days. The floods lasted in each case one or two days, and the sum of the turbidities for the one-tenth of the whole number of days when the water was muddiest was 55 per cent. of the aggregate of all the turbidities for the period.

The last set of observations is for a large river, with a drainage area of over 11,000 square miles, and extends over a full year. In this period there were sixteen floods, each lasting from one to six days, and the sum of the turbidities for the one-tenth of the whole number of days when the water was muddiest is 45 per cent. of the aggregate turbidities for the year. The floods occurred on an average of once in twenty-two days, and the average duration was two and one-half days.

The results are very striking as showing that a very large proportion of the mud is carried by the water in flood-flows of comparatively short duration. They also show that in small streams the proportion of mud in the flood-flows is greater and the average duration of floods is shorter than in larger streams. In other words, the differences between flood- and low-water flows are greatest in small streams, and gradually become less as the size of the stream increases.

When a stream is used for water-works purposes in the usual way, a certain quantity of water is taken from the stream each day, which quantity is nearly constant, and is not dependent upon the condition of the stream or of the volume of its flow. The proportions of the total flows taken at high- and low-water stages are very different, and it thus happens that the average quality of the water taken for water-works purposes is different from the average quality of all the water flowing in the stream.

Let us assume, for example, a stream having a watershed of such a size that in time of moderate floods water from the most distant points reaches the water-works intake

in twenty-four hours. Let us assume further that rain-falls of sufficient intensity to cause floods and muddy water occur, on an average, once in ten days, and that the turbidity of the water at these times reaches 1·00, and that for the rest of the time the turbidity averages 0·10. Let us assume further that at times of storms the average flow of the stream is 100 units of volume, and for the nine days between storms the average flow is 10 units of volume. We shall then have in a ten days' period, for one day, 100 volumes of water with a turbidity of 1·00, and nine days with 10 volumes each, or a total of 90 volumes of water, with a turbidity of 0·10. The total discharge of the stream will then be 190 volumes, and the average turbidity 0·57. The turbidity of 0·57 represents the average turbidity of all the water flowing in the stream, or, in other words, the turbidity which would be found in a lake if all the water for ten days should flow into it and become thoroughly mixed without other change.

Now let us compute the average turbidity of the water taken from the stream for water-works purposes. The water-works require, let us say, 1 volume each day, and we have for the first day water with a turbidity of 1·00, and then for nine days water with a turbidity of 0·10. The average turbidity of the water taken by the water-works for the period is thus only 0·19 in place of 0·57, the average turbidity of the whole run-off.

The water flowing in the stream is thus just three times as turbid as the water taken from the stream for water-works purposes.

It is often noted that with long streams the water becomes muddier further down, and it may naturally be thought that it is because of the added erosion of the stream upon its bed in its longer course. This, of course, may be a cause, or the lower tributaries may be muddier than the upper ones, but the fact that the water taken at the lower place is more muddy than further up is not an indication of this.

Let us take, for example, a water-shed of twice the size of that assumed above; that is, so long that forty-eight

hours will be required for the water from the most remote feeders to reach the water-works intake. Let us divide this shed into two parts, which we will assume to be equal, one of which furnishes water reaching the intake within twenty-four hours, and the other water reaching the intake between twenty-four and forty-eight hours. Now suppose a storm upon the water-shed producing turbidities equal to those just assumed for the smaller stream. On the first day the water from the lower half of the shed, namely, 100 volumes having a turbidity of 1·00, passes the intake, but this is mixed with 10 volumes of water from the upper half of the water-shed having a turbidity of 0·10, and the total flow is thus 110 volumes of water having a turbidity of 0·92. On the second day the water from the lower half of the water-shed has returned to its normal condition, and the flood-flow of the upper half of the water-shed, 100 volumes with a turbidity of 1·00, is passing and mingles with the 10 volumes from the lower half with a turbidity of 0·10, and the total flow is again 110 volumes having a turbidity of 0·92. The following eight days, until the next rain, will have flows of 20 volumes each with turbidities of 0·10. The average turbidity of all the water flowing off is 0·57, as before, but the water taken for water-works purposes will consist of 2 volumes of water with turbidities of 0·92, and 8 volumes with turbidities of 0·10, making an average turbidity of 0·26.

By doubling the length of the water-shed we have thus doubled the length of time during which the water is turbid, and have increased the average turbidity of the water taken for water-works purposes from 0·19 to 0·26, although the average turbidity of all the water running off remains exactly the same.

If now we assume a water-shed so long that three days are required for the water from the most remote points to reach the intake, with computations as above, water taken for water-works purposes will have an average turbidity of 0·32; and with still longer water sheds this amount will increase, until with a water-shed so long that ten days are required for the water from the upper section to reach

the intake, and the average turbidity of the water taken for water-works purposes will reach the average turbidity of the run-off, namely, 0·57.

In the above computations the numbers taken are round ones, and, of course, would not represent actual conditions. They do serve, however, to illustrate clearly the principle that the larger the water-shed, other things being equal, the more muddy will be the water obtained from it for water-works purposes, and the longer will be the periods of muddy water, and the shorter the periods of clear water between them.

It cannot be too strongly emphasized that the period of duration of muddy water is dependent upon the length of time necessary for the muddy water to run out of the stream system after it is once in it, and be replaced by clear water; and that the settling out of the mud in the river has nothing to do with it. The absence of deposits of the fine clay which is so freely carried by flood-flows is the best evidence of the lack of sedimentation in Pennsylvania streams.

Muddy waters are principally the results of rains upon the surface of ground capable of being washed, and the turbidity of the stream at any point below will occur at the times when the muddy water reaches it in the natural course of flow, and will disappear again when the muddy water present in the stream system at the end of the rain has run out, and has been replaced with clear water from underground sources, or from clearer surface sources.

Having now considered briefly the causes of turbidities in streams, and the circumstances which control their duration, let us consider the measures which can be taken for reducing or removing them from public water supplies.

We have first the use of reservoirs. Reservoirs serve two purposes in connection with water drawn from streams; they allow sedimentation, and they afford storage. If a water having a turbidity of 1·00 is allowed to remain in a sedimentation basin for twenty-four hours, the turbidity may be reduced by as much as 40 per cent., or to 0·60. If it is held a second day the additional reduction is much less.

If samples are taken of the water in the reservoir before

and after settling and sent to the chemist for analysis, he will probably report that from 70 to 80 per cent. of the suspended matters have been removed by the process. The suspended matters are removed in much larger ratio than the turbidity. This arises from the fact that there is a certain proportion of comparatively coarse material in the water as it is taken from the river. This coarse material increases the weight of the suspended matters without increasing the turbidity in corresponding degree. In twenty-four hours the coarser materials are removed completely, and at the end of that time only the clayey or finer particles remain in suspension. It is these clayey particles, however, that constitute the turbidity which is most objectionable in appearance, and which is most difficult of removal by filtration or otherwise.

After the water has settled for twenty-four hours, if the figure representing the turbidity is multiplied by 16 it will express approximately the weight of the suspended matters remaining in the water, in parts per 100,000. With the water as it is taken from the river, it is necessary to use a larger factor for this purpose, factors of 30, 50 and even 100 being required, according to the character of the suspended matters.

Sedimentation thus removes the heavier matters from the water, but it does not remove the finer matters which principally affect the appearance of the water, and are otherwise more troublesome. A sedimentation of twenty-four hours removes practically all of the coarser matters, and the clayey material remaining at the end of that time can hardly be removed by further sedimentation. The economical limit of sedimentation is about twenty-four hours.

Sedimentation has practically no effect upon the clearer waters between flood periods.

Let us now consider the effect of a sedimentation basin or reservoir holding a twenty-four hours' supply of water, into which water is constantly pumped at one end and constantly withdrawn from the other, upon the water of a stream of such size that the time of passage from the feeders to the intake is less than twenty-four hours. During the period be-

tween storms the water is comparatively clear and passes through the sedimentation basin without change. When a storm comes the water in the stream promptly becomes muddy, and muddy water is supplied to the reservoir; but, owing to the time required for water to pass through it, the outflowing water remains clear for some hours. There is a gradual mixing, however, and, long before the expiration of twenty-four hours, somewhat muddy water appears at the outlet. The turbid water period rarely lasts in streams of this size more than twenty-four hours, and at the expiration of that time the water in the sedimentation basin is as muddy or muddier than the water flowing in the stream. After the height of the flood the stream clears itself by the flowing away of the turbid water much more rapidly than the water clears itself by sedimentation in the reservoir. That is to say, if at the time of maximum turbidity we take a certain quantity of water from the stream and put it aside to settle, at no time will the improvement by settling equal the improvement which has taken place in the stream from natural causes. Generally, the improvement in the stream is several times as rapid as in the sedimentation basin, and the water from it will at times have only a fraction of the turbidity of the water in the basin.

Let us now consider what the sedimentation has done during our assumed ten-day period. For eight days of clear water it has done nothing. For the day of the flood very much clearer water has been obtained from it than was flowing in the stream. For the day following the flood the water in the sedimentation basin has been more muddy than the water in the stream. The only time when the sedimentation basin has been of use is during the first part of the flood, that is, the part in which the turbidity of the water in the stream is increasing. During this period it has been of service principally because of its storage capacity, yielding up water received from the stream previously, when it was less muddy. Such sedimentation as has been secured is merely incidental and not important in amount.

It will be obvious from the above that for these con-

ditions storage is much more important than sedimentation. This brings us back to the old English idea of having storage reservoirs large enough to carry water-works over flood periods without the use of flood waters. Reservoirs of this kind were, and still are considered necessary for the successful utilization of waters of many English rivers, although these waters do not approach in turbidity the waters of some American streams. This idea of storage has been but little used in the United States.

In the above case, if we use our reservoir for storage instead of as a sedimentation basin, the average quality of the water can be greatly improved. The reservoir should be kept full during clear-water periods, and pumping to it should be stopped whenever the turbidity exceeds a certain limit, to be determined by experience, and the reservoir is then to be drawn upon for the supply until the turbidity again falls to the normal. In the case assumed above, with a stream in which all of the water reaches the intake in twenty-four hours, a reservoir holding a twenty-four hours' supply, or in practice, to be safe, a somewhat larger one, would yield a water having an average turbidity of only 0·10 as against an average turbidity of 0·19 for water pumped constantly from the stream without a reservoir.

With a river having a water-shed so long that forty-eight hours are required to bring the water down, a reservoir twice as large would result in a reduction of the average turbidity from 0·26 to 0·10, an improvement absolutely impossible with sedimentation alone.

As the stream becomes larger and the turbid periods longer, the size of a reservoir necessary to utilize this action rapidly becomes larger, and the times during which it can be filled are shortened, and thus the engineering difficulties of the problem are increased. For moderately short streams, cost for cost, storage is far more effective than sedimentation, and we must come back to the old English practice of stopping our pumps during periods of maximum turbidity.

Neither storage nor sedimentation is capable of adequately removing mud from water. The process can only

be finished by filtration. Two methods of filtration have been extensively used for this purpose. These are known as sand and mechanical filtration. They differ principally in that the rate of filtration with mechanical filtration is many times greater, and that the process is assisted by the use of coagulant, which forms a flocculent precipitate in the water, which draws the particles of sediment together and allows them to be more readily removed by filtration.

With either sand or mechanical filtration the difficulty in treatment, as I shall show, increases nearly in direct proportion to the turbidity, and it is thus highly important to secure a water for filtration with as little turbidity as possible, and thus to develop to their economical limits the preliminary processes of storage and sedimentation.

Let us consider the nature of the agencies which in filtration lead to the removal of turbidity. First there is the straining action, which consists in stopping particles too large to go through the passages in the filter. Straining is an important element in filtration, but it is never adequate in itself. If the passages of a filter are made so small as to stop even tolerably well the finest particles of sediment, they are so small as to make it impracticable to get adequate quantities of water through them. Any filter which acts as a strainer only can remove only the larger particles, and not the smaller ones, which so largely constitute the turbidity.

The next agency of importance in the work is adhesion. When the particles of suspended matters are carried into contact with the filtering material, many of them get close enough to it to adhere to it and remain fixed while the water flows on without them. Closely connected with adhesion, but differing from it, is, third, sedimentation taking place in the pores of the filter. In the removal of suspended matters from water by sedimentation, we may assume that owing to its weight and the viscosity of the water, each particle will make a certain rate of progress downward through the water. With the smaller particles this rate of progress is extremely slow, and with a sedimentation basin several feet deep many days may be required for a particle

to reach the bottom, and in fact its progress may be entirely offset by currents in the sedimentation basin, resulting from the action of the wind or from temperature changes, which constantly mix the water up from top to bottom and absolutely prevent the deposit of the finest particles. With a sedimentation basin that is not so deep, the improvement in a given time becomes greater, owing to the shorter courses for the particles. If it is filled with coarse gravel or other loose material through which the water very slowly flows, particles have to settle only to the first stone or other obstruction with which they come in contact, and the lengths of the courses of the particles are greatly reduced and the improvement correspondingly increased. It thus happens that by putting water through even quite a coarse material, so coarse that no straining whatever can be conceived as taking place in it, the improvement in its appearance may nevertheless be quite marked.

In a filter the conditions for sedimentation are still further greatly improved. The spaces between the sand grains are extremely small, and the course of a particle from any point in the interstices to the sand grains next below is very short, and when a particle strikes bottom it is perhaps assisted in remaining there by adhesion, especially where the grains of filter sand have accumulated organic growths more or less sticky in their natures. Sedimentation in the filter beds thus becomes an important factor in clarification.

It is essential for these processes that the rate of filtration shall not be so great as to sweep the particles forward when they come in contact with particles of the filtering material instead of allowing them to remain upon them.

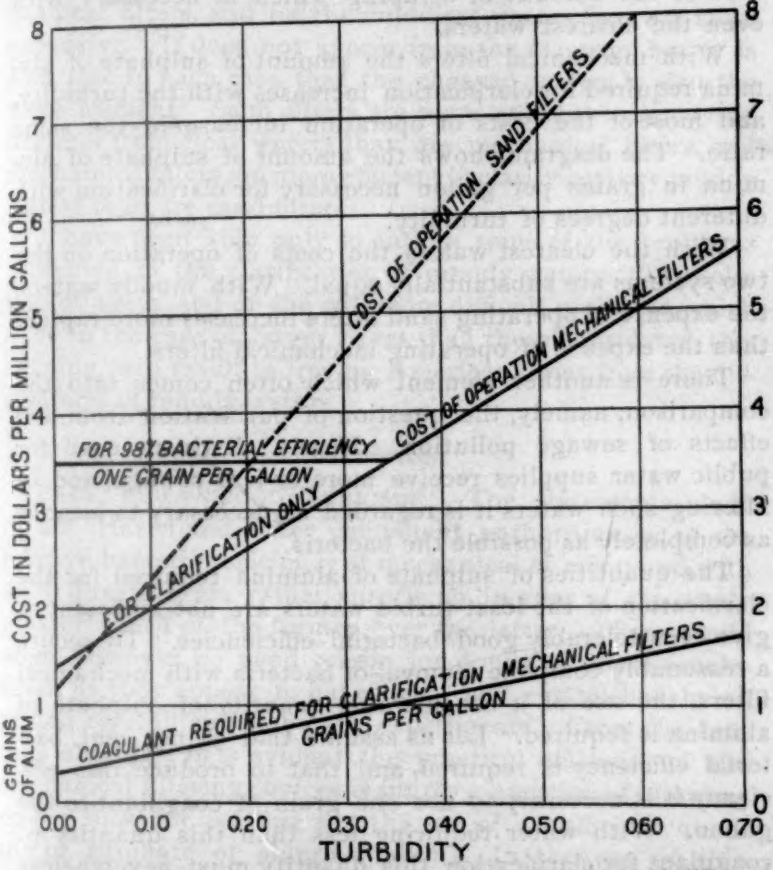
These three agencies constitute the clarifying power in sand filtration without coagulant. In mechanical filtration the rate of filtration is greatly increased, and all of them, and especially the last two, are very much limited in their action. The velocity of flow is so great as not to allow of either sedimentation or adhesion, or at least not in anything like the degree in which they operate in sand filtration. On the other hand, a new agency is introduced, which is the fourth on our list, namely, coagulation.

The most common and successful coagulant is sulphate of alumina. Waters to be treated with it generally contain lime in solution as calcium carbonate. This reacts with the sulphate of alumina, forming calcium sulphate, which remains in solution, and aluminum hydrate, which forms a flocculent precipitate which surrounds and gathers together the finest particles in the water and forms them into aggregates which are removed by straining much more readily than the separate particles can be removed. The characteristic feature of filtration with coagulants consists in gathering the particles into aggregates and removing them as such.

One of the essential conditions of success in the use of coagulant is that the raw water shall contain more than enough lime to decompose the sulphate of alumina applied. The flood-flows require much larger quantities of coagulant for their clarification than do the waters at other times, and they usually contain much less lime than the normal flows. The reason for this is obviously that the water of the flood-flows is mostly composed of rain water which has come over the surface and without coming into very intimate contact with the soil, and consequently without having taken from it much lime, while the low-water flows contain a considerable proportion of water which has percolated through the soil and thus become charged with lime. It thus becomes an important question whether the flood-flows of a given stream carry enough lime to decompose the sulphate of alumina necessary for their clarification, and it may happen that serious difficulties will be encountered at these times, even with waters which ordinarily present no difficulty in this respect.

Regarding these two systems of filtration, it can be said that, within certain limits, each is capable of removing mud satisfactorily. In filtration without coagulant the rate of filtration must not be too great, especially with very turbid waters. It is more difficult oftentimes to remove the finest clay particles than to remove the bacteria: and to secure clarification, rates of filtration must be employed lower than would be necessary for bacterial purification.

I recently made some estimates of cost of clarifying waters of various degrees of turbidity by sand and mechanical filters. These estimates were made for a special set of conditions, and I do not know that they will fit others, but




**Cost of operating sand and mechanical filters with waters of different degrees of humidity. Turbidity of water applied to filter is taken without reference to reduction by preliminary processes. Interest and depreciation charges are not included.**

they have at least a suggestive value. The results shown by the diagram include only the cost of operation, and not interest and depreciation charges.

With sand filters the frequency of scraping is nearly proportional to the turbidity, and as scraping represents most of the expenses, the costs of operation are proportional to the turbidity, except the general costs, and the cost of the amount of scraping which is necessary with even the clearest waters.

With mechanical filters the amount of sulphate of alumina required for clarification increases with the turbidity, and most of the costs of operation increase in the same ratio. The diagram shows the amount of sulphate of alumina in grains per gallon necessary for clarification with different degrees of turbidity.

With the clearest waters the costs of operation on the two systems are substantially equal. With muddy waters, the expense of operating sand filters increases more rapidly than the expense of operating mechanical filters.

There is another element which often comes into the comparison, namely, the question of purification from the effects of sewage pollution. Nearly all rivers used for public water supplies receive more or less sewage, and in filtering such waters it is regarded as necessary to remove as completely as possible the bacteria.

The quantities of sulphate of alumina required for the clarification of the least turbid waters are not sufficient to give even tolerably good bacterial efficiencies. To secure a reasonably complete removal of bacteria with mechanical filters, the use of a considerable quantity of sulphate of alumina is required. Let us assume that 98 per cent. bacterial efficiency is required, and that to produce this efficiency it is necessary to use one grain of coagulant to the gallon. With water requiring less than this quantity of coagulant for clarification, this quantity must nevertheless be used, and the costs will no longer decrease with decreasing turbidity.

I have added this line to the diagram, and this, combined with the upper portion of the line showing cost of clarification, represents the cost of treating waters with mechanical filters, where both bacterial efficiency and clarification are required.

This line, considered as a whole, increases much less rapidly with increasing turbidity than does the corresponding line for sand filters, and the two lines cross each other. With the clearest waters sand filters are cheaper than mechanical filters, and for the muddiest waters they are more expensive. It does not appear from the diagram, but it is also true in each case, that the cheaper system is also the more efficient. Sand filters are more efficient in removing bacteria from clear waters than are mechanical filters, and mechanical filters are more efficient in clarifying very muddy waters than are sand filters.

I have been able only to outline some of the problems presented in the clarification of muddy waters. The solution of them, and of the still more difficult problems which arise in the case of larger rivers than those considered this evening, will result in freeing American cities from the discomforts of muddy waters.

DISCUSSION.

PROF. F. LYNWOOD GARRISON:—The statements made by Mr. Hazen and other competent authorities, as to the relative bacterial efficiency of mechanical as compared with sand filtration, are rather surprising in view of the vastly greater speed of the former over the latter. There would seem, however, no good reason for doubting these conclusions, as they appear to have been well established by repeated careful and elaborate experiments. From the data thus obtained it is evident the practical efficiency of the mechanical filtering devices is simply a question of allowing proper time for settling and the use of a sufficient quantity of sulphate of alumina (alum). In the use of this chemical compound lies the essential difference between the two systems, and it is a question whether the cure is not worse than the disease, since the objectionable bacteria are replaced by the probably equally deleterious alum.

It has been well established that certain disorders may be directly traced to the continuous consumption of drinking water purified with the use of alum. Briefly, they may be said to consist of a general impaired digestion, irritation

of the mucous membrane of the digestive tract, and if gastric troubles already exist, very serious consequences may follow the habitual use of water possessing astringent properties. As is well known such water is also quite objectionable for some industrial purposes, and in the bath and laundry.

The neutralization of the alum present in water can, of course, be effected by the use of lime or other alkalies, but the operation is at best a delicate one when performed upon a necessarily large scale, since the chemical composition of the water is probably seldom if ever constant, and the amount of alum used must vary from day to day in accordance with the quantity of matter held in suspension and the variable number of bacteria present as indicated by the biological test. There are, therefore, grave objections to the treatment by such complicated methods of the water-supply of our large cities. The simplest filtration method, even if the slowest and most costly at the beginning, will doubtless in the end prove the more effective and cheapest. The problems here presented are of the greatest and most vital importance to the city of Philadelphia, whose water-supply at present is undoubtedly contaminated by sewage and rendered disagreeable to the senses by the large and miscellaneous variety of suspended matter contained therein.

MR. P. A. MAIGNEN:—I should like to ask Mr. Hazen if, in the figures he gives us as representing the cost of operating mechanical filters, he has included the cost of the filtered water needed for washing the sand.

This represents a considerable item which should not be lost sight of. For instance, according to Mr. Fuller's report on the Louisville experiments, it is estimated that additional filters should be provided in times of average turbidity equal to 30 per cent., and at times of flood equal to 75 per cent. of actual requirement in order to clarify the water needed for washing the sand.

In other words, if the quantity to be filtered at the Queen Lane Reservoir be 70,000,000 gallons daily; in times of flood it would be necessary to pump 52,500,000 gallons of water in excess. This water would have to receive the usual

quantity of coagulant, and it would have to be filtered before it is used for washing the sand.

The cost of pumping these additional 52,500,000 gallons would be \$2.12 by $\frac{238}{100}$ feet = \$5.04 per 1,000,000 gallons.

The cost of alum, which at this particular time would be required, would amount to \$7 per 1,000,000 gallons.

The cost of clarifying this water after coagulation would be, according to Mr. Hazen's computation, about \$3.50 per 1,000,000 gallons.

The water needed to cleanse the sand that has filtered 70,000,000 gallons would, therefore, cost \$5.04 plus \$7 plus \$3.50 = \$15.54 per 1,000,000 gallons, multiplied by $\frac{52,500,000}{70,000,000}$ = \$11.65 per 1,000,000 gallons, in addition to the cost of filtering the water for city use.

Mr. Hazen admitted that this cost was not included in the cost of operation of mechanical filters as shown in his diagram.

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*Special Meeting, January 3, 1899.*

## METHODS FOR THE EXAMINATION OF EXPLOSIVES.

By W. J. Williams, F.I.C., F.C.S.,
Member of the Institute.

In this paper I intend to give a brief outline of the methods used for the examination of smokeless powders, as laid down by the regulations of the War Department and practiced at Frankford Arsenal.

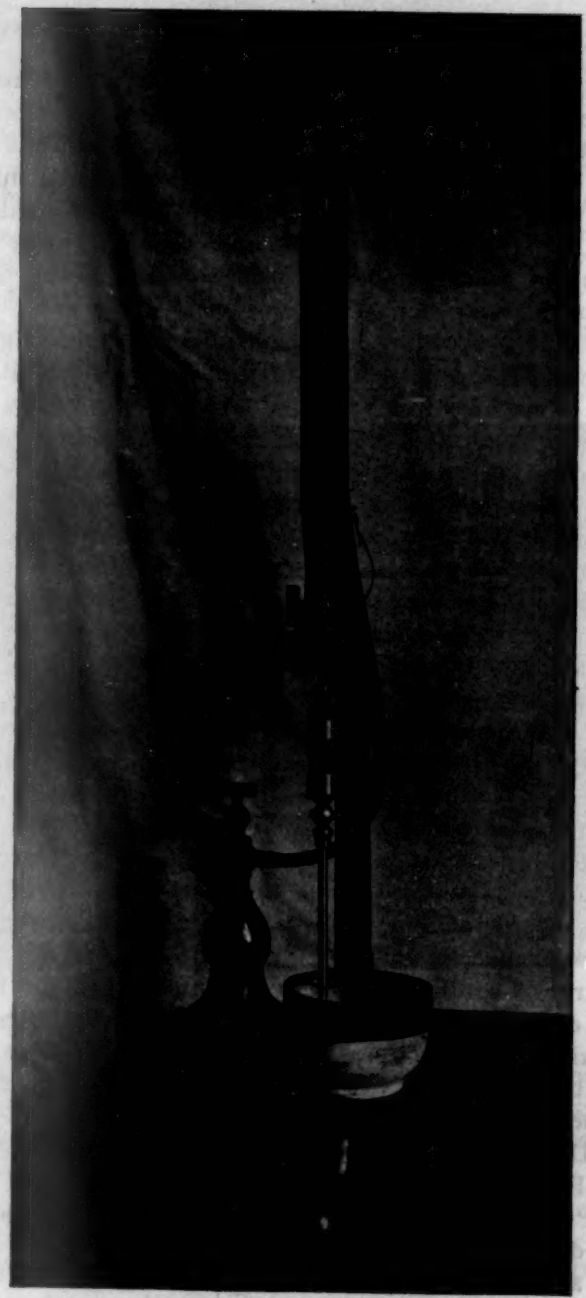
In general, the ingredients of smokeless powders used in the service are nitro-glycerine, gun-cotton or nitro-cellulose and sometimes a salt of picric acid, usually ammonium picrate. To these are added small quantities of inert materials, such as oil or paraffin, resin, urea, camphor, etc., for the prevention of decomposition and for modifying the rate of combustion.

In the first place we will consider the "service tests" of a smokeless powder.

The first point taken into consideration is the "stability" of the powder, *i. e.*, its liability to decomposition under the influence of heat. This is measured by the length of time that the powder will stand a temperature of 150° F. before the nitro compounds suffer decomposition; and is carried out in this way. Potassium iodide is re-crystallized from alcohol, and 1 gram is dissolved in 250 cubic centimeters $H_2O$. Three grams starch, previously well washed in distilled $H_2O$, are added to 250 cubic centimeters water, slowly heated to boiling, and boiled gently for fifteen minutes. The two solutions are then mixed. Strips of well washed filter paper are dipped in the mixture for ten seconds, and are then hung up to dry in a warm, dark place, free from laboratory fumes. These strips are then cut into suitable lengths, about 25 millimeters by 10 millimeters for the test.

When used they are moistened on the upper half with a drop of a 20 per cent. solution of glycerine in water.

The test is made in a cylindrical water bath, heated by an outer hot water bath to a temperature of 150° F. or 65° C. The bath in which the test is made has an aperture of about 5 inches diameter. It is covered with a loose sheet of copper, pierced with four or five holes just large enough to receive the test tubes, which are held in place by converging slips of brass wire, which act as springs. The material to be tested is then placed in the test tube, occupying a depth of about $\frac{1}{2}$ inch; a piece of filter paper is affixed to a platinum hook on the end of a glass rod (which passes through the rubber cork closing the test tube) and moistened with a drop of glycerine solution, and the tube passed through an orifice in the lid of the bath (which has been previously heated to 150° F. or 65° C.) to such a depth that the powder is just immersed. Soon after the tube has been introduced a ring of moisture forms a little way up the tube, and then the position of the test paper is fixed by adjusting it so that the line of demarcation of the wet and dry portion of test paper coincides with the lower edge of



Du Pont densimeter.

the ring of moisture. When, under the action of heat, the nitrogen oxides or acids are set free, they decompose the KI and a faint yellow or brown line is formed on the paper. If this coloration is produced in less than fifteen minutes, the powder is considered unstable. The temperature of 170° F. or 77° C. for gun-cotton, and of 180° F. or 82° C. for cordite and other explosives, is prescribed by the English home office.

The next proceeding is to determine the specific gravity. The absolute specific gravity of a powder is determined by means of mercury in a vacuum. A cylindrical glass vessel or vase is mounted in metal fittings, so that it can be screwed in place at the foot of a shortened barometer tube. To the lower end of this is screwed a hollow metal tube, so as to bring the whole apparatus to its proper height with the graduations marked on the upper portion of the barometer tube. The lower end of this hollow metal tube dips in a reservoir of mercury. First the vase is screwed into place, the tube adjusted, and then by means of an air pump a vacuum is produced until the mercury rises to the height of the barometer, thus completely filling the vase. The temperature of the mercury is accurately noted and the vase is detached and accurately weighed. It is now emptied of mercury, a known weight of powder introduced, and again replaced in position. A vacuum is produced as before, and the mercury again raised to the barometric height, thus filling all the unoccupied space in the vase. The vase is unscrewed and reweighed, again noting temperature of mercury. The difference between this weight and the previous one gives the weight of mercury at the noted temperature which occupies the same space as the known weight of powder. Now we have all the data for calculating the absolute density of the powder.

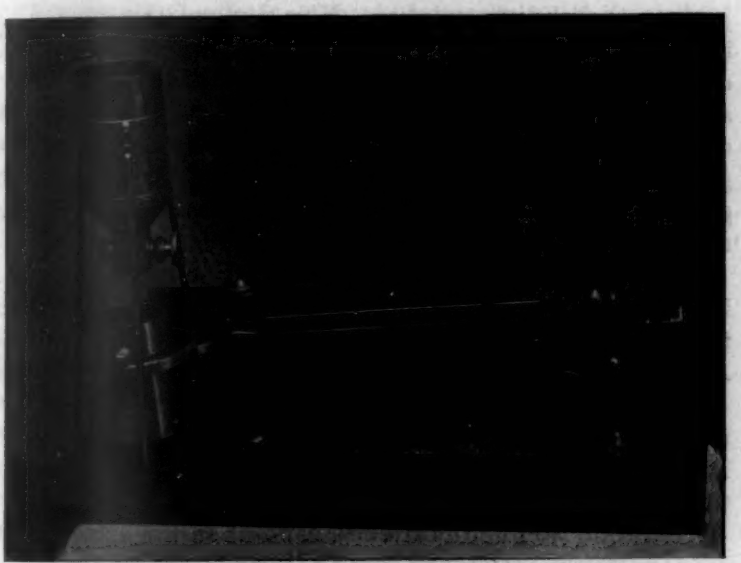
If D = density of powder sought,
P = weight of vase filled with mercury,
P′ = weight of vase filled with mercury and powder,
d = density of mercury at Tx°,
a = weight of powder taken,

$$\text{then } D = \frac{d \times a}{P - (P' - a)}$$

P′ — a = weight of vase, Hg and powder
— weight of powder taken
P — (P′ — a) = weight of Hg displaced by powder.

The next thing to be determined is the gravimetric density. This is not easy to define. A rough definition is "the weight of the grains of powder including the air in the interstitial spaces contained in unit volume." Perhaps a better definition would be:

"The ratio which the weight of the substance bears to the volume it occupies."



Du Pont gravimetric balance.

It is obvious that the gravimetric density of a powder is quite distinct from, and independent of, its specific gravity. In fact, a very dense powder may give a much lower gravimetric density than a powder of low specific gravity. Gravimetric density is usually expressed by the weight of a cubic foot in ounces.

The instrument used to determine the gravimetric density is known as the Du Pont gravimetric balance. It con-

sists of a small beam scale resting on a steel knife edge, one end of which terminates in a semi-circular jaw, which supports a vase hanging on trunnions. The other arm of the beam is graduated into 100 equal parts, marked from 800–900, which are read as ounces. Below the 900 mark is a small hook, to which weights marked 100 and 200 ounces can be attached when necessary.

To ascertain the gravimetric density, the vase is placed in position on the knife edges of the jaw, the counterpoise is placed in it, the 100-ounce weight hooked on and the rider set at 800, and then the beam is put into equilibrium by adjusting the sliding weights. Now remove the vase, fill it lightly with powder from the hopper, without any jarring or shaking, till it overflows and then "strike" it with a straight edge. Replace the vase on the jaw and again produce equilibrium by the weights and rider. The figures give the gravimetric density without calculation, as the graduations are so arranged that the vase filled with distilled water would show 1,000 on the scale.

Powders are then submitted to various exposures. A known weight, on a fine sieve, is placed in an air bath heated to 130° F. for twenty-four hours. The loss of weight noted. Another portion, also on a fine sieve, is exposed on a tray in a box, with tight-fitting cover, over water, so that it remains in an atmosphere saturated with moisture for twenty-four hours; and the increase of weight noted, also the temperatures prevailing during the test in the hygroscope.

A second weighed portion is exposed in the same way to moisture for twenty-four hours, the temperatures being noted also, weighed to ascertain the moisture absorbed and then exposed on a glass plate to a free current of air, protected from any loss by draughts, for a further twenty-four hours, and the weight again noted. This shows the powder's power to throw off the moisture previously absorbed in the hygroscope, by simple exposure to air. The variation in the temperature and the humidity of the atmosphere is carefully noted during the exposure. Another weighed portion is exposed, similarly, directly to air and the gain or loss of weight noted. The temperature and humidity are also observed.

A weighed portion of powder is exposed in an air-tight box to extreme cold from —35° F. to —40° F. for six hours, and the gain or loss in weight noted. It is then exposed to the air for twenty-four hours, and the gain or loss of weight noted.

The powder, as received from the manufacturer, is, of course, tested in the proof house for the velocity it imparts to the projectile and for the pressure exerted in the gun. After each of the above-mentioned exposures to heat, moisture, moisture and air, air, and cold and air, respectively, the velocity and pressure produced are tested, so that the practical effects of each exposure on the powder, or the variation in its practical effectiveness caused by each exposure, is ascertained. Cartridges are loaded with the powder and are exposed to heat at 130° F. for twenty-four hours, to moisture in the hygroscope for one week, and to cold of —35° to —40° F. for six hours, in precisely the same way, then fired to ascertain the variation in the velocity and pressure produced in the made-up cartridges by these exposures.

The condition of granulation of the powder causes great variation in the rate of combustion, and consequently in the velocity of the projectile and the pressure on the gun. It is, therefore, very necessary that the granulation of each shipment should vary as little as possible from that of previous shipments, or that the granulation should be uniform. The powder is sieved through a set of sieves having circular perforations ranging from ·10 inch to ·09, ·08, ·07, ·06, and ·03 inch, and the proportion resting on each sieve weighed.

Lastly a weighed portion of the powder is fired on a watch glass and the residuum of ash weighed. This represents roughly the "fouling" capacity of the powder.

This series of tests constitute what are known as the "Service tests" of the powder.

## CHEMICAL TESTS.

The power or effectiveness of an explosive may be approximately measured by its content of nitrogen. Thus:

| | | | Per cent. |
|---|---|---|---|
| Cellulose | $C_{12}H_{14}O_4\ (O.H)_6$ | | |
| Hexa-nitro-cellulose | $C_{12}H_{14}O_4\ (O.No_3)_6$ | contains | 14·14 |
| Penta-nitro- " | $C_{12}H_{15}O_5\ (O.NO_3)_5$ | " | 12·75 |
| Tetra-nitro- " | $C_{12}H_{16}O_6\ (O.NO_3)_4$ | " | 11·11 |
| Nitro-glycerine | $C_3H_5\ (O.NO_3)_3$ | " | 18·50 |
| Picric acid | $C_6H_2O.H.\ (NO_2)_3$ | " | 18·34 |
| Potassium nitrate | $K.NO_3$ | " | 13·86 |
| Sodium nitrate | $NaNO_3$ | " | 16·47 |

The readiest means of estimating nitrogen in a nitrate or nitric ester is by Crum's method, viz.: By dissolving the substance in concentrated sulphuric acid and then violently agitating with metallic mercury. The nitric acid is decomposed with formation of nitric oxide, NO, and mercury sulphate. The volume of nitric oxide gas liberated is corrected for temperature and barometric pressure according to the formula

$$V^1 = \frac{V \times B}{760 \times (1 + \delta t)}$$

and as 1 cubic centimeter of NO gas = 0·6267 milligram N the content of N can be readily calculated from the NO gas found. Lunge's Gas Volumeter, in which the gas evolved is transferred to another burette for reading and which is provided with a "reduction" tube or air vessel, whereby the gas evolved can be at once compressed to its true volume, saves much calculation. It has a further advantage over the ordinary form of nitrometer in that the gas is separated from the acid, so that no correction need be made for this column of acid. A smokeless powder is of a tough, horny character, very difficult to grind, and unless in a very fine state of division, very slow to dissolve in concentrated $H_2SO_4$. I find a good way of handling it is to file or rasp off a sufficiency of the powder, sieve through a 60-mesh sieve and take the fine portion for nitrogen estimation. It is desirable to use as little $H_2SO_4$ as possible for solution, for two reasons; one is that NO gas is appreciably soluble in $H_2SO_4$, the solubility is 0·21 cubic centimeter NO gas in 15 cubic centimeters $H_2SO_4$; and the other is that if a large amount of $H_2SO_4$ is used the quantity of NO gas evolved is always a little too low. This is probably due to an incomplete decomposition of the nitric

acid from the difficulty of obtaining perfect contact with the mercury when the quantity of acid is too large. About 300 milligrams of powder is a very convenient quantity to operate upon. This is placed in the cup of the nitrometer and 4 or 5 cubic centimeters of concentrated $H_2SO_4$ poured upon it. It is stirred and rubbed against the sides of the cup with a platinum or glass rod at intervals and the cup closed with a cork. Generally a smokeless powder takes about four hours to completely dissolve, very seldom less time. The text-books say that the solution is ready for decomposition *as soon as it will flow* but my experience is that unless solution is *perfect* the results will be too low. Even a finely divided gun-cotton requires about two hours for perfect solution. Apparently it is all dissolved in about thirty minutes, but a close scrutiny will show that it is in a translucent gelatinous form; and I find it seldom fully dissolves under two hours. The solution is run into the nitrometer, the cup carefully rinsed with dilute $H_2SO_4$ (1 volume concentrated $H_2SO_4$ to 1 volume $H_2O$), of which it is desirable to use as little as possible. By rinsing with about 1 cubic centimeter at a time in a pipette, I find that 4 to 5 cubic centimeters are sufficient for perfect rinsing. The use of dilute $H_2SO_4$ for rinsing always gives results about 0·2 per cent. higher than if concentrated $H_2SO_4$ is used. This I believe is due to the rise in temperature giving a more perfect reaction with the mercury. It has been suggested that the high result is due to the aqueous vapor introduced, but I do not consider this probable as there is present at least 6 cubic centimeters concentrated $H_2SO_4$ to 2 cubic centimeters $H_2O$ (or about 10·8 grams acid to 2 grams $H_2O$) and that seems amply sufficient acid to retain all $H_2O$. When the rinsing is completed the nitrometer is shaken violently till the reaction is over. It is advisable to repeat this shaking once or twice. The instrument is left at rest twenty to thirty minutes to equalize temperature with the surrounding atmosphere. Then the gas is transferred to the measuring burette, the volume corrected for temperature and pressure and the N calculated from the volume of gas found. It is important that the mercury in the measuring burette should be perfectly dry as any aqueous

vapor makes a very appreciable difference in the volume of gas.

The gas volumeter as designed by Lunge is a far preferable instrument to the ordinary nitrometer. When the "reduction" tube has been once filled with the quantity of air at the temperature and barometric pressure of the laboratory equal to 100 cubic centimeters at normal temperature and pressure, this remains good (with ordinarily good taps well greased and carefully closed) for at least two weeks, thereby saving much unnecessary calculation; of course, if the gas volumeter has not been used for a few days, it is always well to take a double reading—one at the current temperature and pressure and again when the air in the reduction tube is compressed to normal temperature and pressure. The first reading, when corrected, should equal the second reading, if no leakage has occurred.

It is always desirable to take the N determination by this method on a perfectly dry sample of powder. The method is only applicable to nitrates and nitric esters, which give up NO on agitation with mercury. It is, of course, inapplicable to nitro-substitution compounds such as picrates, nitro-naphthaline, etc., in which case I find a modified Kjeldahl or Gunning method the readiest and most accurate process for N determination.

About 0·5 gram of the finely-ground sample is placed in a long-necked Kjeldahl digestion flask, and 30 cubic centimeters of concentrated $H_2SO_4$ (in which 2 grams of salicylic acid quite free from N. has been dissolved) are poured over it, and it is set aside till completely dissolved. This frequently requires many hours. When solution is complete add gradually 5 grams crystallized sodium thiosulphate. Then heat gently till the violent reaction and frothing has subsided. Add a drop of metallic mercury and boil briskly till the liquid is colorless or of a pale amber yellow. This frequently requires four to six hours with a tough horny powder. Finally, complete oxidation with a little potassium permanganate. The oxidation can be much accelerated by adding 5 to 10 grams powdered potassium sulphate about fifteen minutes

after boiling has commenced, as proposed by Gunning. When oxidation is complete, the flask is cooled and its contents transferred to a distilling flask with about 200 cubic centimeters water, and a little zinc or platinum to prevent bumping. Add a little potassium sulphide solution to decompose mercury compounds and then sufficient sodium hydrate to render the contents of the flask alkaline; distil over into semi-normal acid and titrate with decinormal ammonia. This is a very accurate method and very useful as a check on the nitrometer determinations.

It may be interesting to show the close agreement in determinations by the nitrometer and by the Kjeldahl method:

| | N. by Nitrometer. Per Cent. | | By Kjeldahl. Per Cent. | Diff. |
|---|---|---|---|---|
| Sm. powder | 13·632 | | 13·654 | 0·020 |
| " " | 14·305 | | 14·246 | 0·059 |
| " " | 13·475 | | 13·462 | 0·013 |
| " " | 13·936 | | 13·986 | 0·050 |
| German Sm. powder | 13·509 | | 13·465 | 0·034 |
| " " ballistite | 12·836 | | 12·823 | 0·013 |
| Gun-cotton | 12·662 | | 12·660 | 0·002 |
| " | 13·152 | | 13·096 | 0·056 |
| Picric acid theory | 18·340 | found | 18·337 | 0·003 |
| Sm. powder, Nas nitric ester | 12·449 | | | |
| Calculated from percentage of picrate | 4·865 | | | |
| Total N | 17·314 | " | 17·435 | |
| Sm. powder, Nas nitric ester | 11·509 | | | |
| Calculated from percentage of picrate | 4·552 | | | |
| Total N | 16·061 | " | 16·046 | |
| | | " | 16·122 | |

## MOISTURE AND VOLATILE MATTER.

Most powders, and gun-cottons in the colloidal condition, have been dissolved in acetone, amyl acetate or other solvent in the course of manufacture; and although the bulk of this solvent is removed, the powder still retains 1 or 2 per cent. The fine sample is exposed to a temperature of 50° C. (120° F.) in an air bath for twenty-four hours. The air bath is fitted with a thermostat, so that a constant temperature is maintained. After twenty-four hours' exposure

to 50° C., the sample is placed in a desiccator over concentrated $H_2SO_4$ or $CaCl_2$, and a good vacuum produced by a Sprengel or other air pump. As a rule, twenty-four hours in a vacuum is sufficient, though sometimes a particularly horny and tough sample will require even longer.

For safety in transit, nitro-glycerine is frequently mixed with acetone, which has to be removed before estimating the nitrogen. This is done by adding water to the mixture, which dissolves the acetone and the mixture is transferred to a separating funnel, and the heavy nitro-glycerine soon settles and can be run off through the tap. The washing with water is repeated two or three times, and it is well to let the last washing stand over night to allow the water ample time to separate. A funnel is prepared by plugging the stem with asbestos and half filling it with dry salt, NaCl; the nitro-glycerine is filtered through this NaCl, which removes the last traces of moisture. It is then ready for the determination of N in the gas volumeter.

## ANALYSIS OF EXPLOSIVES.

In the first place we will consider a simple explosive, *e. g.*, gun-cotton.

The determinations are moisture, "soluble cotton," pyroxylin or collodion, which is a mixture of penta- and tetra-nitro-cellulose, gun-cotton or hexa-nitro-cellulose, unnitrated cotton or cellulose, and ash, and, of course, total nitrogen.

The moisture and nitrogen we have already considered. A very excellent, but slow, method of determining the pyroxylin is to extract a weighed portion of the cotton with methyl alcohol in a Soxhlet's extractor. This is accurate, but very slow, as the cotton gelatinizes and chokes the linen filter. The *modus operandi* is as follows: A thistle tube has its stem plugged loosely with glass-wool, a perforated platinum disc overlays this plug and this is covered by a linen filter. The weighed portion of gun-cotton is introduced. The tube placed in the Soxhlet extractor and the lower bulb filled with methyl alcohol and heated in a hot water bath. The extraction takes five or six days; of course it requires

but little attention, and practically runs itself. All that is required is to replace the evaporated water in the bath and to see that the temperature does not get too high. When extraction is complete the thistle tube and its contents are dried at 50° C. and reweighed the loss = pyroxylin.

The gun-cotton is extracted from the residue in precisely the same way, but acetone or acetic ether is the solvent used, and the loss of weight = gun-cotton. The residue is unnitrated cotton or cellulose.

An equally accurate and much quicker method of estimating pyroxylin is to weigh out, say 3 grams of the sample and transfer to a graduated cylinder of a capacity of 150 cubic centimeters. Now add 50 cubic centimeters absolute alcohol and allow the cotton to soak and disintegrate for say thirty minutes, then add 100 cubic centimeters pure ether and shake at intervals for twelve hours or more. Allow to settle, withdraw 50 cubic centimeters of the solution and evaporate to dryness in a platinum basin, the residue is pyroxylin. This can be checked by withdrawing a second portion of 50 cubic centimeters and precipitating the pyroxylin with chloroform and filtering through a weighed linen filter. It is advisable to redissolve this precipitate in a mixture of 1 part alcohol and 2 parts ether, and reprecipitate with chloroform, dry the precipitate at 50° C. and weigh. This second precipitation is obligatory in a powder which also contained nitro-glycerine, otherwise nitro-glycerine is retained in the gelatinous pyroxylin.

Cellulose or unnitrated cotton is estimated in this way: A weighed portion, about 5 grams, of the sample is treated with 30 cubic centimeters of a saturated solution of sodium sulphide, or sodium stannite, and boiled for thirty minutes and allowed to stand twenty-four hours, settled and the solution decanted. It is then boiled with a second portion of 30 cubic centimeters saturated sodium sulphide solution and then filtered on a weighed filter and washed with $H_2O$. Then washed three or four times with a 5 per cent. solution of hydrochloric acid to remove any metallic salts, washed free from acid with water, dried and weighed. The filter is then incinerated, the ash weighed and deducted

from the previous weight. The remainder equals cellulose.

The ash of a gun-cotton is determined by mixing a weighed portion in a platinum crucible with melted paraffin, cautiously heating until the paraffin inflames, and allowing it to burn away slowly, finally raising the heat till only the ash remains unconsumed.

### ANALYSIS OF A POWDER.

The analysis of a powder containing nitro-glycerine, a picrate and gun-cotton with paraffin or oil, resin, camphor, sulphur, urea, metallic salts, etc., is a very complicated and tedious procedure.

The finely divided and dried sample is first treated with ether, either in a Soxhlet extractor or in a flask, and poured through a linen filter. The ether dissolves out the nitro-glycerine, paraffin or oil, camphor, resin and part of the sulphur, and part, if not all, of the picrate. The loss of weight represents total ether extract.

If picrates are present the ether extract is mixed with water in a separator, the picrates pass into the water solution, which is then separated from the ether solution.

The ether extract is cautiously evaporated, best let it evaporate spontaneously, as it is almost impossible to prevent loss of nitro-glycerine if the temperature be raised.

The dried extract is treated with carbon disulphide, the $CS_2$ is decanted into a weighed beaker, this is repeated three or four times, then the $CS_2$ is cautiously evaporated and the camphor volatilizes along with the $CS_2$. Now let A represent the weight of the total ether extract. Let B represent the residue of A after extraction with $CS_2$, and let C represent the residue left of the $CS_2$ extract after the $CS_2$ and camphor have evaporated, then $A - (B + C) =$ weight of camphor extracted by $CS_2$ and volatilized with it.

Having determined the camphor, the two residues are mixed together and digested with sodium hydrate on a water bath, mixed with ether and separated.

The ether solution contains the oil and paraffin, which is weighed after evaporating the ether.

The water solution is oxidized with bromine, HCl is

added, which precipitates the resin, which is filtered and weighed on a filter of known weight. The sulphur which has been oxidized by bromine is precipitated as $BaSO_4$ and ignited and weighed.

After treatment with ether the powder is next extracted with hot water. This dissolves any picrates, urea and metallic nitrates and chlorates and water-soluble salts. The picric acid is precipitated by cinchonine sulphate, and the metallic salts are determined by the usual well-known methods.

There now remains the pyroxylin, true gun-cotton, cellulose and ash, which are determined as previously described in the analysis of gun-cotton.

Instead of extracting with ether alone, the first extraction may be made with a mixture of 1 part alcohol to 2 parts ether. This extracts pyroxylin in addition to all the substances dissolved by ether, and the pyroxylin is precipitated by chloroform and filtered. This gelatinous precipitate should be redissolved in ether-alcohol and reprecipitated to remove all the nitro-glycerine.

If metallic salts are present besides nitrates, chlorates and other water-soluble salts, and they usually are, as sodium carbonate, or carbonates of the alkaline earths are generally used to finally neutralize the gun-cotton, they are extracted from the residue left after treatment with sodium sulphide. This residue consists of cellulose and these metallic salts insoluble in water. This residue is treated with hydrochloric acid and the metallic salts determined in the usual way.

Powders are frequently graphited; this gives them a glossy black appearance, and is said to prevent the absorption of moisture.

## APPENDIX.

THEORY OF GUN-COTTON.—*Formation from Cellulose.*

$$C_{12}H_{16}O_4(O.H)_6 + 6HNO_3 = C_{12}H_4O_4(O.NO_2)_6 + 6H_2O$$

According to the theory of Eder he produced

| | Per Cent. | |
|---|---|---|
| $C_{12}H_{14}O_4(O.NO_2)_6$ Hexa-nitro-cellulose, containing 14·14N | { | insoluble in ether and alcohol. |

| | | Per Cent. | |
|---|---|---|---|
| $C_{12}H_{15}O_5(O.NO_2)_5$ Penta- | " " " | 12·75N | soluble in ether and alcohol. |
| $C_{12}H_{16}O_6(O.NO_2)_4$ Tetra- | " " " | 11·11N | soluble in ether and alcohol. |
| $C_{12}H_{17}O_7(O.NO_2)_3$ Tri- | " " " | 9·15N | soluble in ether and alcohol. |
| $C_{12}H_{18}O_8(O.NO_2)_2$ Di- | " " " | 6·76N | soluble in ether and alcohol. |

but he did not succeed in producing mono-nitro-cellulose.

Vicille made gun-cotton, with an excess of acid, at a temperature of 11° C., and found eight stages of nitro-cellulose, therefore, he assumed the formula of cellulose must be doubled, and assigned these formulæ to the different stages.

| $C_{24}H_{20}O_9(OH)_{12}$ Cellulose. | Per Cent. | |
|---|---|---|
| $C_{24}H_{16}O_9(NO_3H)_{11}$ Endeca-nitro-cellulose, cont'g | 13·47N | insoluble in ether and alcohol. |
| $C_{24}H_{20}O_{10}(NO_3H)_{10}$ Deca- " " " | 12·75N | insoluble in ether and alcohol. |
| $C_{24}H_{22}O_{11}(NO_3H)_9$ Ennea " " " | 11·96N | soluble in ether and alcohol. |
| $C_{24}H_{24}O_{12}(NO_3H)_8$ Octo- " " " | 11·11N | soluble in ether and alcohol. |
| $C_{24}H_{26}O_{13}(NO_3H)_7$ Hepta- " " " | 10·18N | gelatinous in ether and alcohol. |
| $C_{24}H_{28}O_{14}(NO_3H)_6$ Hexa- " " " | 9·15N | slightly attacked by ether and alcohol. |
| $C_{24}H_{30}O_{15}NO_3H)_5$ Penta- " " " | 8·02N | slightly attacked by ether and alcohol. |
| $C_{24}H_{32}O_{16}(NO_3H)_4$ Tetra- " " " | 6·76N | slightly attacked by ether and alcohol. |

These formulæ are not generally accepted. Gutmann has made gun-cotton with 13·65 per cent. N on a very large scale, which would be impossible, according to Vicille's theory.

Gun-cotton is a nitric ester or nitric ether. Concentrated sulphuric acid decomposes it, liberating nitric acid. Concentrated potassium hydroxide and sodium hydroxide form the corresponding nitrates with slow re-formation of cellulose at ordinary temperatures; this action is quickened at a temperature of 60° to 80° C.

At high density of charge (about 0·20) gun-cotton decomposes thus :

$$2(C_{24}H_{20}(O.NO_2)_{11}) = 24CO_2 + 24CO + 12H_2O + 17H_2 + 11N_2$$
$$46{\cdot}19 + 29{\cdot}40 + 9{\cdot}45 + 1{\cdot}49 + 13{\cdot}47 \text{ per cent.}$$

and 1,143 grams yield 1,168 calories, water considered gaseous.
or 1,227 " " " liquid.
or 1 kilogram yields 1,022 " " " gaseous.
or 1,074 " " " liquid.
and 859 liters of gas, at constant pressure

At low density of charge (about 0·023) its decomposition is

$$2(C_3H_{29}(O.NO_2)_{11}) = 18CO_2 + 3OCO + 18H_2O + 11H_2 + 11N_2$$
$$34{\cdot}65 + 36{\cdot}75 + 14{\cdot}17 + 0{\cdot}96 + 13{\cdot}47 \text{ per cent.}$$

and 1,143 grams yield 1,140 calories, water considered gaseous.
or 1,230 " " " liquid.
or 1 kilogram yields 998 " " " gaseous.
and 1,076 " " " liquid.
and 859 liters of gas at constant pressure.

It will be observed that neither NO nor other nitrous oxide gases are produced by explosive decomposition in closed vessels. When the gases are allowed to escape freely under a pressure about equal to that of the atmosphere, then NO is formed. But the products of decomposition vary according to the conditions of density of charge, pressure exerted, and so on very greatly, especially if the gases are allowed to cool, but remain fairly constant at constant pressure.

Nitro-glycerine is a nitric ester or nitric ether of glycerine. Its formation is according to the equation

$$C_3H_5(OH)_3 + 3HNO_3 = C_3H_5(O.NO_2)_3 + 3H_2O$$

Potassium and sodium hydroxides decompose it, forming the corresponding nitrates and glycerine. If it were not a nitrate, but a nitro compound, it would produce amido compounds when reduced by nascent hydrogen, ammonium sulphide, etc , as nitro-benzene and picric acid do under similar conditions.

A di-nitro- and mono-nitro-glycerine can be conjectured, and it is probable they are formed and at once dissolved by the excess of $H_2SO_4$. They are also soluble in water. Liecke says that by using nitric acid of sp. gr. 1·3 he produced mono-nitro-glycerine, and by using acid of sp. gr. 1·4 he formed di-nitro-glycerine, and with acid of sp. gr. 1·5, he obtained tri-nitro-glycerine. These statements have not been verified.

Henriot claims he made mono-nitro-glycerine by mixing glycerine with dilute $HNO_3$ (1 part acid to 3 parts water). He says it is easily soluble in water and alcohol, difficultly soluble in ether, and does not explode by shock.

Nitro-glycerine in large quantities explodes at 180° C. (356° F.). Nitro-glycerine decomposes thus:

$$2(C_3H_5(O.NO_2)_3) = 6CO_2 + 5H_2O + 3N_2 + O$$
$$58{\cdot}20 + 19{\cdot}80 + 18{\cdot}50 + 3{\cdot}50 \text{ per cent.}$$

and 227 grams yield 331·5 calories, water considered gaseous.
or 356·5 " " " liquid.
or 1 kilogram yields 1,460 " " " gaseous.
or 1,570 " " " liquid.
and 713 liters gas at constant pressure.

It may be interesting here to compare the calories and volumes of gas evolved by black powders and their solid residues.

BLACK POWDERS

of the general composition, potassium nitrate 75 per cent., sulphur 10 per cent., charcoal 15 per cent. This composition will be approximately expressed by the formula $16KNO_3 + 21C + 7S$, and the explosive decomposition by

$$16KNO_3 + 21C + 7S = \underbrace{13CO_2 + 3CO + 8N_2}_{27{\cdot}34 + 4{\cdot}11 + 10{\cdot}71} + \underbrace{5K_2CO_3 + K_2SO_4 + 2K_2S_3}_{32{\cdot}88 + 8{\cdot}32} + \underbrace{\quad}_{16{\cdot}64}\ \text{p.c.}$$

Gases 42·16 + Solids 57·84 p.c.

Gay-Lussac found that 1 liter = 900 grams of sporting powder evolved

| | |
|---|---|
| 238 liters | $CO_2$ |
| 22·5 " | CO |
| 189 " | N |
| 449·5 " | gas. |

Bunsen and Schischkoff obtained from 1 gram of powder 0·3138 gram gases = 193·1 cubic centimeters @ 0° C., and 760 millimeters, and 0·6806 gram solids.

Linck obtained from 1 gram of powder 0·358 gram gases = 218·35 cubic centimeters @ 0° C., and 760 millimeters and 0·6415 gram solids.

These solids and gases had the composition :

| Solids. | B. & S. | Linck. |
|---|---|---|
| $K_2SO_4$ | 62·10 | 45·08 |
| $K_2CO_3$ | 18·58 | 23·96 |
| $K_2S$ | 3·13 $K_2S_3$ | 14·94 |
| $K_2S_2O_3$ | 4·80 | 5·83 |
| $2(NH_4)3CO_2$ | 4·20 | 3·18 |
| C | 1·07 | 2·85 |
| $KNO_3$ | 5·47 | 1·87 |
| KSCy | 0·45 | 1·81 |
| S | 0·20 | 0·48 |
| | 100·00 | 100·00 |

| Gases. | B. & S. | Linck. |
|---|---|---|
| $CO_2$ | 52·67 | 52·14 |
| CO | 3·88 | 4·33 |
| N | 41·12 | 34·68 |
| H | 1·21 | 1·63 |
| $H_2S$ | 0·60 | 7·18 |
| O | 0·52 | 0·04 |
| | 100·00 | 100·00 |

Karolyi obtained from 1 gram powder 0·3078 gram gases = 206·91 cubic centimeters @ 0° C., and 760 millimeters, and 0·692 gram solids.

Noble and Abel, from 1 gram of different powders : Gases 44·84 per cent. to 41·09 per cent. = 278·3 cubic centimeters to 241·0 cubic centimeters ; solids, 56·82 per cent. to 58·91 per cent. ; calories, 721 to 764.

These results may be compared thus :

1 kilogram gun-cotton evolves 1,074 calories and 859 liters gas.
1 kilogram nitro-glycerine " 1,570 " " 713 " "
1 kilogram black powder " say 740 " " 260 " "

or gun-cotton evolves about three times as much gas as black powder and about one and one-half times as many calories ; and nitro-glycerine evolves

about two and one-half times as much gas as black powder and about twice as many calories.

Therefore, the potential energy of gun-cotton may be roughly considered as about four and one-half times that of black powder and the potential energy of nitro-glycerine may be roughly estimated as about five times that of black powder.

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*Stated Meeting, October 18, 1898.*

## THE FIELD FOR CHEMICAL IMPROVEMENT IN THE MANUFACTURE OF SUGAR.

BY WILFRID SKAIFE.

I wish to lay before you, as far as the limits of this paper will admit, a general idea of the field which the sugar industry presents to the chemist and chemical engineer for original research. The paper is written from the practical sugar-makers' point of view, and deals with those problems which present themselves daily to us, and whose solution is of commercial as well as scientific importance. The pure chemistry of the various sugars is not touched upon, for, while the work to be done in this direction cannot be overestimated, the field is too extensive.

To those who are familiar with practical sugar chemistry, it may seem that this field, in the present state of our knowledge, has been pretty well worked out, for no other industry has had more able chemists devote themselves to its study. From the time of Dubrunfaut, to whose wonderfully original mind we owe so much, a great number of good men have produced much good work. Robert, Scheibler, Stammer, Peligot, Berthelot, Casamajor, Maumene, Soxhlet, Biot, Lippman, Wiley, Stohman, Wiechman, Prinzens-Gerlig, Claassen and many others have built up a great literature of sugar. Through them our knowledge of the chemistry of sugar has been developed, and many great improvements in the extraction thereof, from the sugar-producing plants of the world, have resulted; but to indicate how little real advancement has been made for a long

time, it may be pointed out that the latest and best beet sugar-house that has been erected this year, is constructed to use the method of clarification of the juice, described by MM. Perier & Possoz in the *Comptes Rendus* of August, 1860, and modified later on by Jelinek, and that the latest refinery is using the same char-decoloration process, discovered by Derosne, in 1812, and rendered practical by Dumont in 1828. The two great steps in the chemical treatment of sugar liquors—their clarification and decoloration—have remained the same, practically speaking, for forty and seventy years, respectively. Both of these are laborious and expensive processes, and have been subject to steady attack by able men for a long time past, without being even shaken in their position. Other serious problems are still untouched or are the subject of controversy.

I wish now to say that I assume a general knowledge of the manufacturing and refining of sugar, on the part of the readers of this paper, and will, therefore, only indicate the various points at which the skill of the chemist may find a field for the search, without describing minutely the regular daily work.

It is an old German saying that "man haut den Zucker in die Rueben hinein," otherwise, that sugar is made in the fields. The function of the agricultural chemist, in relation to the sugar manufacturer, is one of primary importance, as the work of Maercker, Kuen and Vilmorin, and a host of others can testify. The use of manures, scientifically, and the study of the diseases of the plant have greatly influenced not only the sugar content of the juice of the sugar-beet, but also the nature of the impurities contained therein; for instance, by the suppression, in a great measure, of the use of potash salts, and in some ways of nitrogen, and by the study notably of Dr. Kuehn, of Halle, of the nematoden, whose spread threatened to be as serious to the sugar-beet as the phylloxera to the vineyard. Perhaps to Vilmorin is due, more than to any other, the wonderful result of raising the sugar content of the beet from 8 per cent. to 22 per cent., a triumph of agricultural chemistry, and an indicator of what may be done in this direction

in the sugar-cane fields, where to-day no progress of practical value has been realized. The reasons for this are many; perhaps the greatest being the nature of the countries where the sugar-cane grows, but also, the nature of the plant itself, in that it produces only flowers that are not fertilized in a natural way, the propagation instead being caused by the sprouting of the joints underground. In consequence of this, the crossing of various kinds is nearly impossible, and we go on using the same unimproved plant and relying on empirical knowledge for the selection of the kind. I should state that here is the first and greatest field for the chemist—the study of the improvement of the cane and its economical manuring. Perhaps when the cane-sugar industry shall have such an establishment as we may see connected with the great seedsmen in Europe, where 3,000 or 4,000 polarizations are made in a day to select mother-beets, we may hope for some improvement in the cane fields. Cane has been raised from seed in Java, Demerara and elsewhere, but no practical results have come forth as yet.

Passing from the fields to the sugar-house, we have no chemical problem confronting us in the case of the sugar-cane, for it is, in a well-organized plantation immediately ground up, but sugar-beets, on the contrary, are stored in silos for several months, and a loss of crystalline sugar results, equal often to 2 per cent. on the weight of the beets, or over 10 per cent. of the total sugar in the juice. This loss occurs chiefly in the warmer countries where beet-sugar is made, and is severely felt, for instance, in some parts of France. It will naturally be caused by the sprouting of the beets in the silos, but also occurs apart from this; and to check it until the factory can slice up the whole crop, is a problem worthy of any chemist's skill.

To follow the sugar-beet, first, as it goes through the process of manufacture, the first chemical treatment which it undergoes is the extraction of the juice by means of diffusion. Mathieu de Dombasle, some seventy years ago, started the idea, and Robert of Seelowitz, thirty years afterwards, put into practical shape the process now universally in use, which,

as you are all aware, is an imperfect osmosis, in which the uncut cell walls serve as the membrane and the broken cells discharge their whole content into the surrounding liquor. As handled to-day, the diffusion battery is a very excellent apparatus; the content in the sugar of the refuse being only $\frac{1}{4}$ of 1 per cent. after an hour's contact with water, and the juice of a better quality is obtained more rapidly than in any other way. A great deal has been written concerning the handling of batteries, the question of temperature, etc., but still there remains one important matter from the manufacturers' point of view, and that is the dilution of the juice. Instead of obtaining juice of the same density as in the original beet, we have one containing 10 per cent. to 20 per cent. more water which has to be evaporated later on at the expense of so much fuel. This dilution may be reduced by either raising the temperature of the battery, or by increasing the time of contact, but the former results in the extraction of a more impure juice, and the latter necessitates a much increased capacity. It is possible that a partial solution of the problem, at least, lies in acting on the slices by water under high pressure. It may certainly be assumed that if the process of dialysis is to be relied upon, all we can do to hasten matters is to provide for a more intimate contact between the cell wall and the water, for we cannot change the character of the cell wall without damage to its value as a membrane, nor can we use any liquid except alcohol, which will cause the more rapid passage of the crystalline sugar, and needless to say, its use is not to be considered, on account of the expense.

The diffusion process, so successful in beet-sugar manufacture, has found little application as yet in cane-sugar houses, principally on account of the dearness of fuel in the countries where cane-sugar grows. The grinding of the cane in mills produces a juice without dilution, or of a dilution that can be easily controlled, and is a purely mechanical operation, leaving a residue (bagasse) containing 7 per cent. of sugar, which supplies all the fuel needed for the production of the steam. It seems a wasteful business to burn sugar, but the reduction of the sugar content of

the bagasse by pouring water on the mills is of doubtful value, inasmuch as a great many impurities are carried into the liquor along with the sugar, and an increase in the quantity of molasses produced is the main result.

Having now separated the juice from the fiber, the chemist's attention may be concentrated on the former, and he is confronted with an aqueous solution containing about 15 per cent. of crystalline sugar and 3 per cent. of organic and inorganic impurities, out of which he is to extract as much sugar in as pure and dry a form as possible, and for as little money as possible. Two means of solving this problem present themselves: He may rely on the natural tendency of the liquor to crystallize, and to help this proceed to clarify the juice and then evaporate it, or he may precipitate the sugar from its solution in combination with lime, strontianite or baryta, and subsequently decompose the saccharate.

We know by experience that the first method is the one that is commercially valuable, and that the second one may be used on the final molasses only, after as much sugar as possible has been extracted by crystallization; the great bulk of the saccharate precipitate is the main difficulty in the way of this process, which is chemically very perfect.

The clarification of the juice is a matter on which the attention of chemists has been steadily concentrated now for forty years, without, as I have already said, materially altering the process of Perier and Possoz, who added an excess of caustic lime to the juice, allowed this to settle, thus producing a partial clarification, and then precipitated the greater part of the lime dissolved in the juice by carbonic acid gas. Later on, Jelinek pumped in the gas without waiting for the settling, and precipitated the whole mass together, precisely what we do to-day. The operation is repeated more than once now, and a very clean, clear filtrate is produced, with, however, a considerable expenditure in labor and machinery. It is a violent remedy considering the small amount of impurities we have to deal with, but it is our only one. Its principal defects are the great quantity of lime needed (equal to 3 per cent. on the

weight of the raw material), necessitating special limekilns and involving voluminous precipitates, whose separation from the filtrate needs pressure filters of great size and strength, and whose washing free from sugar means more water to evaporate.

The efforts that have been made to replace this clarification have been various in kind, and many in number, but only those which tend to produce a similar precipitation in the presence of the impurities with other reagents have had any success. Very beautiful liquors may be produced by the action, for instance, of lead acetate, of alumina, of soluble phosphates, of tannic acid, etc., but the practical sugar-maker has never been able to see wherein an improvement lay over the ancient carbonatation process. This process is generally described as an entanglement of the impurities in the falling calcium carbonate, but it may be looked upon as nothing more than a mechanical filtration of a very perfect kind, in which the filtering medium is moved through the liquor instead of the liquor being forced through a cloth, or whatever may be used. It is possible, that by bearing this in mind, we may see our way to avoiding some of the troubles we are now afflicted with, and by performing a similar operation in such a way that a more intimate contact may be arrived at between the liquor and the falling carbonate, as good a result with less expenditure of material may be arrived at.

In cane sugar-houses the elaborate systems of clarification by carbonation and filtration have been tried and found wanting, for we find that by the action of a very small quantity of lime, and some heat, so great an effect is produced, that what would be gained by more perfect work from a purely chemical point of view would be lost commercially, owing to the extra time and apparatus needed. We are much nearer to the solution of the defecation problem in cane sugar, than in beet sugar-houses. Some work which I have carried on for a couple of years in Cuba, leads me to believe that a continuous and almost automatic clarification of cane juice, at a low temperature may be brought about, by extremely intimate mixtures of the lime and

juice in exact quantities, but it would appear that the raw beet juice is too refractory a material to yield to such simple treatment.

The chemist's mind has turned of course with some hope to electricity, for the clarification of juice, and many and exhaustive have been the trials which have been made with this ghost-like element. Great corporations have erected large plants to test the possibility of separating the impurities from the raw juice of the cane and the beet by electrolysis, with the result, as far as the general sugar public know of demonstrating that while a great purification takes place it costs too much horse-power to effect it. These results, however, should not deter the chemist or electrician from further investigation, for it is quite possible that after the great mass of the impurities are removed, we may effect something by the application of the current to concentrated solutions?

In investigating the various methods of clarification, it has been customary to look to the removal of impurities as the standard of value. That is to say, the proportion of sugar to total solids dissolved in the juice is determined before and after clarification and the difference noted. This proportion, the coefficient of purity, as it is called, is the great guide of the sugar-maker for want of a better one. It is manifest, however, that when the quality of the impurities present is not considered, liquors of the same coefficient are not of the same value, and this leads to many errors in the treatment of the juice. Inasmuch as the object of removing impurities is to facilitate crystallization, we ought to attack those substances which give rise to a viscous or gummy condition of the liquor. All our efforts in fact should be directed to producing a medium in which the crystals may move with ease, and I may say, that for some time past I have abandoned tests for everything but viscosity with extremely encouraging results.

The less viscous a liquor is the more perfectly will it filter, and the filtration of liquor is the most important part of its treatment. Could we take the raw juice from the cane or beet and filter it cold through a dense medium,

I doubt whether any further clarification would be necessary, and in well-conducted sugar-houses the greatest care is now taken to produce liquors free from any suspended matter. Five or six different filtrations of the same liquor may now be seen in many beet sugar-houses, but I believe that the mechanical treatment of the juice is only beginning to be understood, and is destined to play a much more important part in sugar manufacturing as well as in other industries. We know now only the use of a filtering medium, through which a liquor passes under pressure leaving impurities on one side; we have yet to observe the action of masses of suspended matter in an extremely minute state of division and brought into contact with the liquor by mechanical means. Mechanical filtration has already wrought one great change in the manufacture of raw sugar, that is, the total suppression of the use of bone charcoal and all its attendant cost and discomfort. Some refineries even are now working high-grade sugars without char, being enabled to produce a cold filtration of heavy liquor through the use of infusorial earth. The passage of this finely divided siliceous matter through the liquor effects the mechanical filtration which the cloths on the filter presses complete. I would strongly recommend the intending investigator to turn his attention towards the production of a substance in the finest possible state of division, and to apply this to liquors which are to all appearances filtered already. In this work the microscope might be used to great advantage. It has yet to play its part in the examination of sugar liquors, and this part may be a mighty one.

I must now turn to the main work of the sugar-house, for which the clarification is a preparation, viz.: the crystallization of the sugar out of its watery medium, and may pass over the reduction of the juice from its content of 18 per cent. solids and 82 per cent. water to 50 per cent. solids and 50 per cent. water, inasmuch as this is an engineer's problem, and presents few chemical aspects of importance. The continuation of the evaporation, however, in the vacuum pan, where the water is reduced to 5 or 6 per

cent., presents a fine opportunity for the study of crystallization, a phenomenon of yearly increasing interest to the chemical world at large. The way the liquor behaves in the pan is the final test of the value of any method of clarification and a check on some methods of extraction. Over 80 per cent. of the total yield of sugar is obtained in this operation, and its proper carrying out is, therefore, of great importance. The study of the effect of high and low temperatures in the steam coils and in the body of the pan affords to-day a very excellent field for investigation. There occurs always in the boiling of the liquor in a vacuum a mysterious and considerable loss of sugar, caused probably, in part, by the action of the heat on the concentrated solution and by entrainment, or the flying of small globules of concentrated liquor upwards to the condenser. As regards the first, much uncertainty exists. As a rule nowadays, steam at about 10 pounds pressure or less is used in the coils for economy's sake, but when time presses, boiler pressure is turned on, and while the amount of available heat is not much greater, the transfer is more rapid from the coil to the liquor. Whether we really lose more sugar with a high temperature in the coils and rapid ebullition than we do at a lower temperature, when the liquor lies closer to the heating surface, is a matter which the chemist can well employ himself with. The excellent work of Dr. von Lippmann in this direction may serve as a basis for further investigation. While the question of entrainment is largely an engineer's problem in which the velocity of the vapor is the principal factor, certain observations made lately in Cuba have led me to believe that entrainment varies much with the nature of the liquor. There always occurs in boiling an entrainment of other matters than sugar, dissolved or suspended in the vapor, a sort of destructive distillation of the non-sugar, as it is called, and it would seem that this leads to a carrying up of crystalline sugar. Further, we do not know as yet whether the entrainment is affected by variations in the temperature and consequently the density of the escaping vapor, the velocity remaining constant.

When a strike of sugar is ready it consists of a mass of crystals, surrounded by a dense syrup, and may at once be centrifugalled, in which process between 60 and 70 per cent. of the weight of the masse-cuite is obtained in dry, raw sugar; or, it may be allowed to cool and crystallize further, in which case from 65 to 75 per cent. of sugar is recovered. A great deal of attention is now being paid to increasing this yield by stirring and cooling the masse-cuite simultaneously for several hours, and thereby promoting the growth of the crystals already formed. This would seem, on the surface, to be a very simple and logical process, but its carrying out requires much care, for there may easily be formed masses of minute crystals (technically known as false grain) whose presence is dreaded in the sugar-house, for either they retard greatly the work of the centrifugals or they involve a great loss by passing through the baskets with the molasses. At present the machinery in use is merely for a general agitation of the mass, but it has struck me that the directing of the flow of the mass in regular currents might greatly increase the regularity of the growth of the crystals. We have the well-known fact to start with, that a crystal will grow if it gets a chance at the expense of smaller crystals, and that a mutilated crystal, as observed by Wulf, will complete itself before other crystals are formed. The well-known work of Behr on crystalline glucose and, indeed, the daily practical experience at a vacuum pan seem to suggest that we may accomplish much by directing the path of the crystals in their journey through the mother-liquor.

After the greater part of the sugar has been centrifugalled out of the first masse-cuite we have to handle a molasses which contains about 20 per cent. of water and 50 to 100 per cent. of sugar in solution, the rest being inorganic and organic impurities. By evaporating some of the water—not too much—and either stirring the mass for a few days or letting it stand for a couple of weeks, a considerable quantity of second-grade sugar crystallizes out, leaving a lower grade of molasses. The simple thickening of this molasses the second time in the vacuum-pan will allow of still further

crystallization, and whether this is done or more complicated means are resorted to, depends on the machinery at hand and the state of the market. The most successful chemical work of the last decade or two has been done in the treatment of the final molasses of beet sugar-houses. Cane sugar-houses produce molasses of a much lower content of crystallizing sugar, and containing a large quantity of invert sugar, which are usually edible, while the presence of great quantities of calcium and potassium salts in the beet molasses render them useless for food and difficult to handle in any way. By Dubrunfaut's osmosis process a quantity of these crystallizable salts may be removed and the sugar crystals allowed to form, or, by the various saccharate processes the sugar may be combined with the alkaline earths and precipitated from its solutions. These are very beautiful processes chemically. But in all of them, and particularly in a case of strontianite, a great deal of machinery is needed, and the low price of sugar is rendering their use very doubtful from the commercial standpoint. It seems strange that given a material which, when evaporated to dryness, contains 50 per cent. of sugar, we cannot induce a crystallization without the expenditure of so much power. Very many attempts have been made to accomplish this by reintroducing the final molasses into the sugar-house, mixing it with the raw juice and carrying it right through to the end; but this must, after a time, produce a mother-liquor of impracticable bulk. The solution of the problem perhaps will come with a greater knowledge of the crytalline life (if I may use such a term) of an impure sugar solution, and how to mechanically assist the straining for union of the widely separated particles.

The limits of this paper do not admit of my dealing at any length with the main problem of the refining of raw sugar, which is its decoloration, and which we may say is produced entirely by the use of animal charcoal. In spite of hundreds of patents for other means, the work of Derosne and Dumont has stood for seventy years or so, as I have already stated. Nobody has been able to produce artificially a means of exposing so advantageously the fine par-

ticles of carbon to the action of the liquor as the curious phosphatic skeleton of the bone affords us, allowing us, as it does, at the same time to collect so easily the carbon from the liquor after use and revivify it. There is no field of research which might perhaps repay the investigator better than that of the decolorizing of sugar-liquors, but anybody who undertakes this had better post himself thoroughly in the literature of the subject, for many surprising laboratory results have been obtained already whose practical value is nil.

I may say, in conclusion, that whatever process a chemist may evolve for the improvement of the sugar industry must be subjected to the most severe practical tests before its adoption will be even considered by the manufacturers in general. All raw sugar-houses now work at very high pressure. They differ from other manufacturing establishments in that they are idle a great part of the year, and they must work at all speed for a few months to get through their perishable raw material. Even a few hours' stoppages may entail a serious loss, and therefore speed and smoothness are primary considerations in the working of any new process. I believe there is a case known of an irate planter, whose work was delayed by a new process, using dynamite one fine morning on the apparatus to clear the path for the resumption of his old system.

Further, the actual value in dollars and cents must be clearly set forth, or the discoverer be satisfied with the scientific value of his work only. Sugar-makers are every day getting pretty circulars about how to get all the sugar out of the raw juice as first product, and similar impossible things, but business-like statements of income and expenditure are rare indeed.

# Mining and Metallurgical Section.

*Stated Meeting, October 12, 1898.*

## ANTHRACITE COAL IN PERU.

By William Griffith, C.E.,
Scranton, Pa.

Anthracite coal has for a long time been known to exist at various points in the Andes Mountains of Peru, and is mentioned in the writings of Peruvian authors and travelers. Up to the present time, however, there has been no use for it, locally. The silver mines, which are plentiful, have always been worked in the most primitive way and never below water level, so that there has been no necessity for steam fuel. Lignite, which gives a flame and is abundant in some places, has been preferred for roasting ores in the lixiviation process, which is the method most extensively in use for the extraction of silver. The climate is such that no artificial heat is required for warmth, and a few sticks or handful of charcoal is sufficient for the primitive methods of cooking in the mountains. There has, therefore, until recently, been no effort made to prospect or in anywise develop the Peruvian coal; consequently, but little is known in Peru of the extent or value of the fields of anthracite in the Andes.

We were called upon, during the past year, to make a hurried investigation of the coal resources of a vast area in northern Peru, and this paper is composed in part of extracts from our report.

### TOPOGRAPHY AND CLIMATE.

The region along the coast of Peru is mostly a desert plain for about 20 miles in width, and to the eastward of this rises the precipitous wall of the Andes Mountains. Near to the coast the climate is temperate and delightful, a continual breeze from the ocean rendering the temperature very regular, as it averages about 70° the year round, occa-

sionally running as low as 65°, and seldom rising higher than 80° in the middle of the day. It seldom or never rains, and the sun shines continually the year round. Of course, this condition of climate prevents the growth of vegetation along the coast. The only tree which grows spontaneously is the Algaroba, which is a hard, tough wood similar to locust, and is used largely for fuel, both for domestic purposes and for power. The soil on this strip of coast land is very fertile. When cultivated by means of irrigation from the streams which flow into the Pacific, it produces luxuriantly all sorts of tropical fruits, rice, sugar-cane, corn, potatoes, yuca, barley and other grains. The climate in the interior portions of the coast land not reached by the tempering winds of the ocean, is somewhat hotter than on the coast, the arid condition existing even to an elevation of about 9,000 feet above the sea.

Passing beyond the limits of the desert land, we come to the foothills of the Andes Mountains. The mountain plateau back of them is about 12,000 feet in height, with the sides toward the ocean deeply plowed by the rugged, precipitous cañons which are cut in their sides by the streams which find their way to the ocean.

Within the limits of the region in question, the following principal streams have their source in the Andes and flow westward to the Pacific, namely: The Chancay, the Sana, the Jequetepecque, the Chicama and the Moche Rivers. These streams, during the wet or summer season, are raging mountain torrents, carrying a large quantity of water. They are impassable and dangerous to ford during this season, but during the dry season of the winter time they become very low, so that oftentimes the water is all taken for irrigation purposes, and none reaches the ocean.

The table-land of the Andes is reached only by means of the narrow, crooked trails, which wind about or up and down over the rocky and precipitous mountain slopes and ravines, which are in places more or less dangerous. These trails can be traversed on horse or mule back, which is the only means of access to the interior. There are two or three railroads which extend from the coast at Pacasmayo, Eten

and Salaverry up the comparatively flat valleys of the larger streams, a distance of 30 or 40 miles, reaching an elevation of about 3,500 feet above tide. None of them, however, are extended up the precipitous slope to the top of the plateau.

After once ascending these steep mountain sides, we find at an elevation of about 10,000 or 12,000 feet, a totally new and entirely different condition of affairs from that which obtains on the coast. The surface has an average elevation of about 12,000 feet. It is covered thickly with a succulent grass known locally as the pampas grass, which grows a foot or 18 inches high, and is a most excellent food for cattle. The surface of the country is much broken and very irregular. Multitudes of mountain peaks are to be seen stretching up from 500 to 2,000 feet above the general level, while the limpid streams which are formed by the copious rains of the wet season, and the occasional showers of the dry season, cut deep channels for themselves through the surface of the plateau. The valleys of these streams, while often steep cañons containing a more or less luxuriant growth of small trees, bushes, ferns, vines, etc., are occasionally broad, fertile valleys which are doubtless susceptible of extreme cultivation. The climate on this mountain plateau during the wet season, is extremely disagreeable and stormy. It rains nearly every day, which causes the trails to become muddy, slippery and extremely dangerous, particularly on the precipitous mountain slopes. During the dry season the weather is very pleasant and averages about 60° at mid-day, and in the higher altitudes, during the night, about 40°, although it occasionally falls as low as 32°. The soil is exceedingly fertile, and in many places can be cultivated without irrigation, producing abundantly, crops of potatoes, alfalfa, corn, wheat and other grains; but owing to the lack of transportation very little land is cultivated except by the Indians on the small gardens or farms around their huts.

This plateau is divided into two parts by a longitudinal ridge about 90 miles distant from and parallel to the coast, having an elevation of 13,000 feet, and with an occasional peak towering far above. This ridge forms the Continental

Divide of South America. The streams previously mentioned, drain the western slope, while the eastward slope is watered by the many streams which flow eastward and northward into the Marañon River, which may be considered as the main source of the central trunk of the Amazon River system. In this vicinity this stream is said to be a swift mountain torrent flowing in a rocky cañon, its course being nearly north, parallel to the coast.

## GEOLOGY.

The geology of this territory, as observed in a hasty way while traveling along the precipitous trails, would seem to consist mainly, near the coast, of a thick formation of red and buff shales apparently of the triassic age. These sandstones and shales are cracked and ruptured in numerous places by dikes of granite, trap and other igneous rocks. They are apparently surmounted in the interior by the more recent rocks of the jurassic, cretaceous or tertiary age, consisting, first, of great thickness (2,500 feet in places) of fine-grained, light-gray or white altered sandstone, approaching quartzite. Overlying this is considerable thickness of softer sandstone, red, yellow and buff shales and black slates, and this is again capped by measures consisting largely of a very thick formation of limestone which, in the vicinity of Hualgayoc and Bambamarca is apparently several miles in thickness and contains many fossil shells of recent age. All of the above formations are most beautifully stratified, and their high and vertical cliffs present a picture delightful to the eye of the geologist.

While the above presents a general idea of the formation of the mountains, the rocks are by no means regularly disposed, being ruptured and distorted in a marvelous manner in places, by the fierce volcanic action which has prevailed in past ages. The cañons cut into the western slope by the streams flowing towards the ocean, present a marvelous picture of rock stratification, showing the formation to be twisted and contorted in all directions, while the eruptive rock consisting of granite, trachyte, porphyry, and all sorts of breccia, tufa, etc., is visible at every turn, and immense

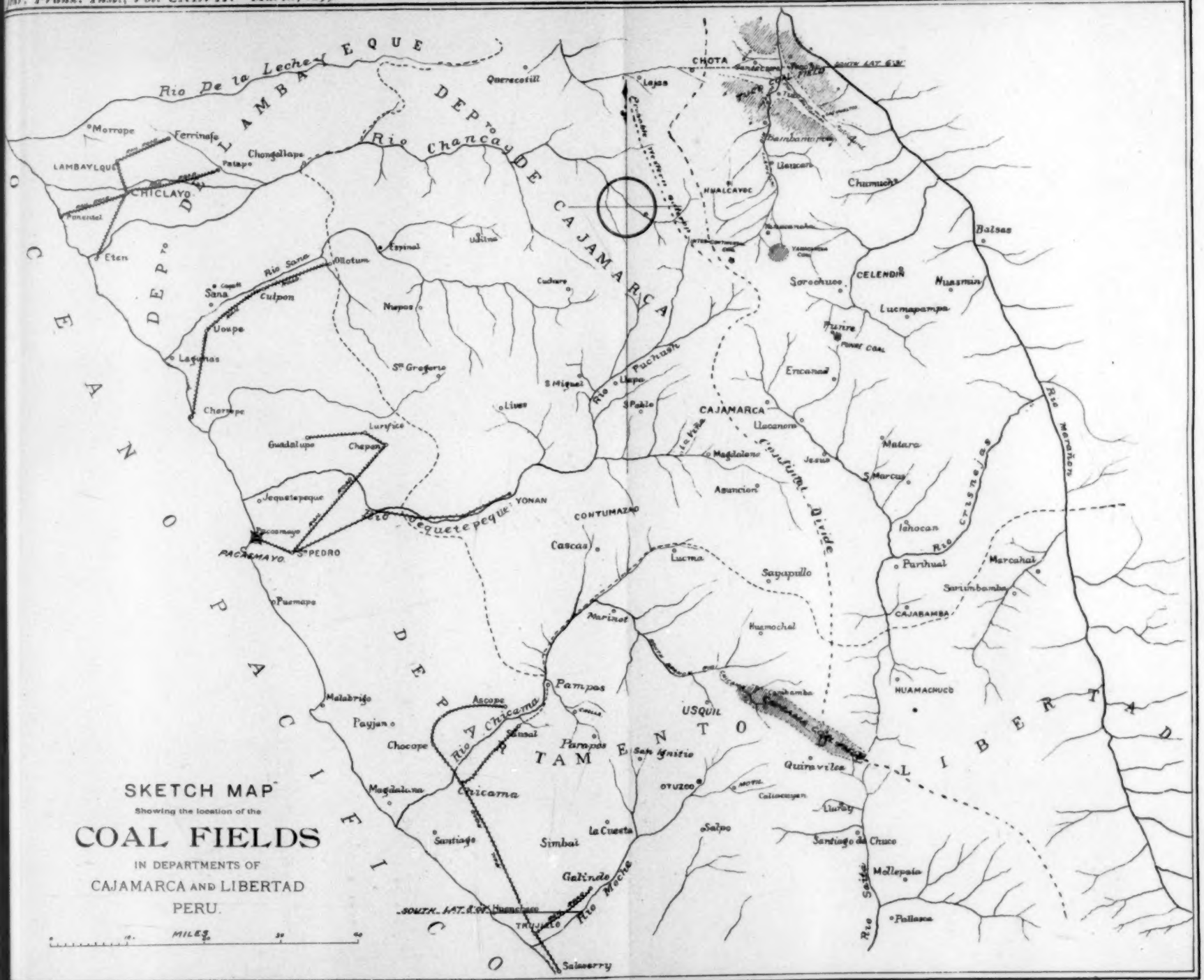
dikes and high mountains of igneous rock are visible scattered about all over the area covered by this territory. Where these dikes have forced their way, the upheaval and distortion of the underlying rock formation due to this volcanic action is plainly to be seen. In some parts these disturbances are more marked than in others; great mountains of trachyte, granite, etc., tower 1,000 or 2,000 feet above the plateau, while in other places the regular sedimentary formation still remains nearly normal, only slightly tilted from the position in which it was originally deposited. In these latter portions of the plateau the stratification is oftentimes quite regular and free from volcanic rupture.

The rock formation where not so much disturbed by volcanic action, is disposed in a series of large basins and saddles. The axes of these saddles or anticlinals have a general direction from the northwest to the southeast. A longitudinal section of the mountain range parallel to the coast would probably show these basins and saddles following one after the other, giving a wavy appearance which would be very much distorted and twisted in the region where it is much disturbed by the upheavals due to the eruptive rocks. Where these basins are very deep we would have them filled by the sandstone and limestone of the more recent age, which are more or less eroded or washed off from the crests of the upward rolls or anticlinals.

## COAL FIELDS.

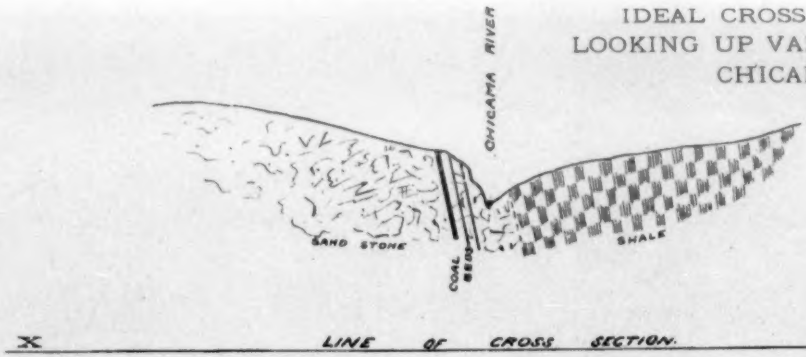
The formation containing the coal beds which occur in this territory is the one described above as a light-gray altered sandstone, to be found 1,000 or 2,000 feet under the limestone referred to before. We would therefore expect to find outcrops of coal where the anticlinals or saddles are of sufficient prominence to raise this formation to the surface, and the coal beds to be in condition for economical mining where the volcanic action was so slight that the stratification is not too much distorted or broken, thus allowing the coal beds to exist in a normal condition, free from the faulting and crushing which would result from fierce volcanic disturbance.

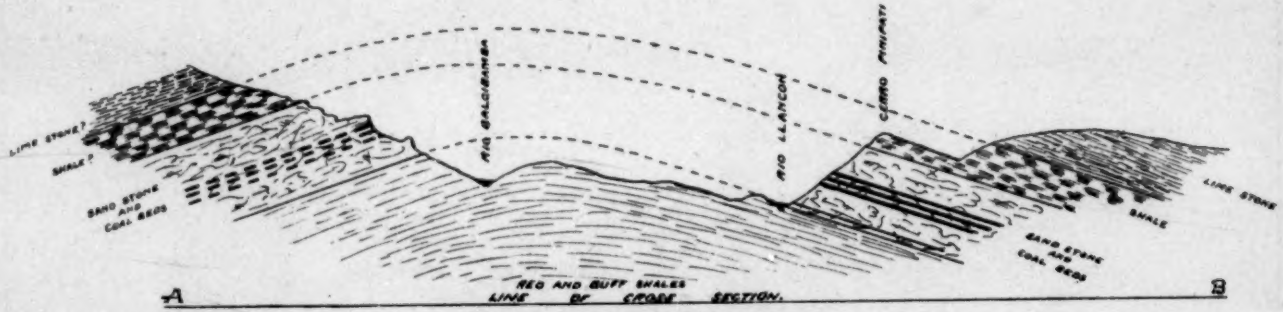
There were two principal regions examined. The one which we shall, for the purposes of this paper, call the Northern or Tuco Field, is located in the northern part of the Department of Cajamarca, about 50 miles north of the ancient Inca City of the same name. The other, about 100 miles south of the first, in the Department of Libertad, which we will denominate the Southern or Chicama Field. To reach the northern field we start from the port of Pacasmayo, on the Pacific Coast, with half a dozen saddle mules and a dozen pack donkeys laden with our provisions, tents, tools, etc., and travel inland about 100 miles, ascending and crossing the Andean plateau and continental divide at an elevation of about 13,000 feet to the town of Hualgayoc, which is located in the bottom of a deep valley about 6 miles to the eastward of the crest of the divide. This town, an ancient and curious one, is the center of a large silver mining region, and the valley is watered by a small mountain torrent flowing eventually to the Amazon, and is enclosed on one side by a high precipitous mountain of beautifully stratified limestone of recent age, containing numerous fossil oyster or other recent shells. The eastward dipping outcrop of this limestone was crossed by the trail several miles before the summit of the divide was reached. The other side of the valley is formed by two large mountains of trachyte, which compose part of an immense upheaval or dike of volcanic rock which extends 20 or 30 miles and forms the Hualgayoc mineral belt, from which silver, copper and other metals have been mined for years by the present inhabitants and their ancestors of the Inca race. From Hualgayoc we traveled northward down the valley of the stream, which soon unites with Rio Llaucon, a branch of the Mariñon, which latter forms the source of the main trunk of the Amazon River system. We continue down the Llaucon for about 30 miles, the main trail leading now along the bottom of the narrow valley and now winding over or round the precipitous mountain ledge. After leaving the igneous rocks of Hualgayoc, our journey lies almost the whole distance over the recent limestone formation previously mentioned, which dips southwestward at an


SKETCH MAP
Showing the location of the
COAL FIELDS
IN DEPARTMENTS OF
CAJAMARCA AND LIBERTAD
PERU.
MILES
Rio De la Leche
LAMBAYEQUE
Rio Chancay
DEPto DE CAJAMARCA
DEPto DE LIBERTAD
DEPto DE PACIFICO
OCEANO
Morrope
Ferrinafe
Chongollape
LAMBAYLQUE
Patapo
CHICLAYO
Eten
Rio Sana
Ollotum
Sana
Culpon
Uoupe
Lagunas
Cherape
Lurifico
Guadalupe
Chapon
Jequetepeque
Rio Jequetepeque
YONAN
PACASMAYO
PEDRO
Pueblo
Querecotill
Lajas
CHOTA
Tambaramayo
Huacaro
HUALGAYOC
Chumuch
Balsas
Sorochuco
CELENDIN
Huasmin
Lucmapampa
Yunire
Encanad
Cochore
Nuepos
Esquinal
Usnine
S. Gregorio
S. Miguel
Rio Llapa
Rio Puchaca
S. Pablo
Lives
CAJAMARCA
Llacanora
Magdalena
Jesus
Asuncion
Matara
S. Marcus
Rio Crisnejas
Rio Marañon
Ichocan
Parhual
Marcahal
Sartimbamba
CAJABAMBA
Continental Divide
Cascas
Lucma
Sapapillo
Huamochal
Marinot
Pampas
Malabrigo
Ascope
Payjan
Chocope
Rio Chicama
Simal
Parapos
Magdalena
Chicama
Santiago
Simbai
la Cuesta
Galindo
Rio Moche
SOUTH LAT. 8° 00'
TRUJILLO
Salaverry
USQUIL
San Ignitio
OTUZCO
Salpo
Quiraviles
Callacocpan
Llurdy
Santiago de Chuco
Mollepata
Pallasca
Rio Saita
HUAMACHUCO
Rio Tambo
SOUTH LAT. 6° 30'

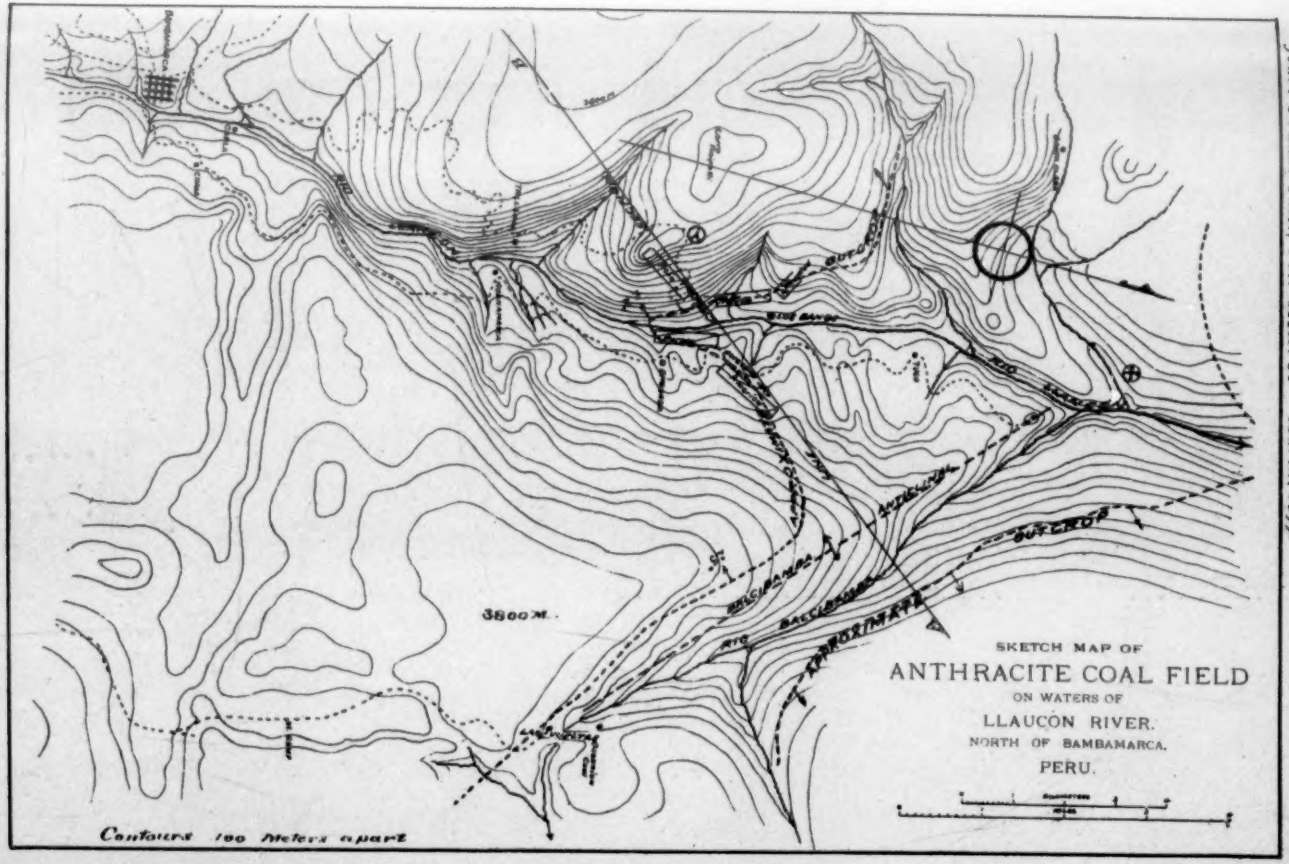
IDEAL CROSS SECTION

IDEAL CROSS SECTION
LOOKING UP VALLEY OF THE
CHICAMA.



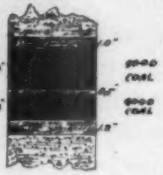

IDEAL CROSS SECTION.
LOOKING UP VALLEY OF THE
BALCIBAMBA.


3800 M.
SKETCH MAP OF
ANTHRACITE COAL FIELD
ON WATERS OF
LLAUCON RIVER.
NORTH OF BAMBAMARCA.
PERU.
Contours 100 Meters apart

## SECTIONS OF TWO COAL BEDS ON EAST SIDE OF LLAUCON RIVER OPPOSITE LOS BAÑOS.

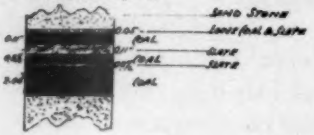
**N°5**

**N°6**




## SECTIONS OF COAL BED —AT— LOS BAÑOS.

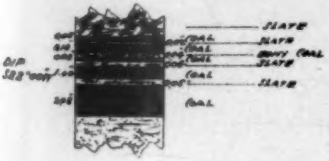
**N° 1**




**N°2**

**N° 3**

**N° 4.**




SCALE, 1 IN.=18 FT.

inclination of about 25°, and is evidently of enormous thickness. We, however, eventually pass below it and our route extends over several miles of the red and buff shales and gray sandstone with an occasional seam of black fire-clay or slate, all dipping southwestward conformably with the limestone. We now find ourselves high on the precipitous mountain side above the river, and we descend by a steep and dangerous trail about 3,000 feet to the bottom of the valley. While passing down we note that the mountain sides are now composed of a fine-grain light gray altered sandstone or quartzite, very hard and very regularly stratified, all dipping about 22° southwesterly. It is near the base of this mountain, about 600 feet above the stream, that we find exposed in the cliffs three beds of fine anthracite coal. This locality is known locally as Los Baños, on account of the warm or hot alum springs which are found at the base of the mountain, formerly doubtless used as a bathing spring. The coal beds are about 50 feet apart, and are respectively 5½, 3 and 6½ feet in thickness, having about the same proportion of slate and interstratified refuse as is common in our Pennsylvania anthracite. The sections of these seams, as measured in some old openings cut in the seam years ago, which are still accessible, are shown on the plate following; that is, No. 1, Other exposures were subsequently noted in the cliffs across the river, a mile distant, which were also measured and are represented in *Plate No. 2.* They are doubtless continuations of the same beds. The coal can only be seen where naturally exposed in the nearly vertical cliffs or washouts along the stream, since the tropical foliage is very dense, and no attempt at prospecting has ever been made. An examination of the topography and geology of the vicinity resulted in the following facts:

About 2 miles further down the Llaucon River another stream, known as the Balcibamba, unites with it, flowing in from the southeastward through a deep valley. The mountains on each side of these two valleys are formed by the thick sandstones of the coal measures, causing high, precipitous cliffs. All the measures to the southward are

noted to dip to the southwest, while those forming the northward side of the Balcibamba Valley dip to the northeast, thus disclosing the fact that the valley of the Balcibamba now follows the axis of an immense anticlinal, the crest of which has been eroded so that the bottom of the valley is now composed of a series of softer red and buff shales and broken sandstone which underlie the quartzite containing the coal. While these coal-bearing sandstones on either side of the anticlinal seem to be very regularly disposed as to strike, dip, stratification, and not much disturbed by volcanic influences, the softer measures underlying them along the anticlinal appear to be disrupted, upturned and much more contorted, which would seem to point to the anticlinal valley of the Balcibama as the center line of greatest disturbance in this immediate vicinity. Standing on a prominence in the valley, the beautifully stratified and regularly dipping rocks of the coal measures may be seen forming the cliffs and mountain tops as far as the eye can reach on either side. We followed the trail leading up the valley of the Balcibamba for 15 miles or thereabout, passing eventually above the sandstone of the coal measures to the rocks of the overlying limestone. Other exposures of coal were noted along the trail; those near to the center of the anticlinal being much disrupted and crushed, while those located further away from the line of disturbance were in much better condition, the coal apparently being of good quality and the bed regular. It must be evident that if these coal beds are as continuous in the measures of the Andes Mountains as coal seams usually are in other parts of the world, that here is a vast coal field with outcrops flanking the mountains for 15 or 20 miles or more on both sides of the Balcibamba and the Llaucon Valleys, and even extending southwestward in the direction of the anticlinal to or across the Mariñon River. So far, our investigation has discovered that this coal field would be composed of two parallel basins extending northwest and southeast, separated by the anticlinal of the Balcibamba Valley. The one basin dipping to the northeast for an unknown distance under the mountain, and perhaps

having its northern margin somewhere near the junction of the Llaucon and Mariñon Rivers. The other basin dipping to the southwest under the limestone measures forming the continental divide between Hualgayoc and the town of Chota. Future explorations may discover its southwestern outcrop 20 miles or more distant on the Pacific slope near the head waters of the Rio Chancay. In some parts of this latter outcrop, however, fierce volcanic action has prevailed which would tend to seriously affect the economic value of the coal seams. So far as we know at the present time, no economical coal beds have been uncovered as yet on the Pacific slope in this northern field. At the southernmost point where our trail crossed the outcropping measures on the Pacific side, indications of coal were prospected, but as the region was much disturbed by the eruptive rocks, the prospect was found to be worthless.

As before stated, the coal bearing quartzite at Los Baños are about 3,000 feet thick, whereas the coal beds mentioned are found near the bottom part of these measures, and the 2,000 feet of overlying rocks were not examined. There is, therefore, a possibility of the existence of other economical beds higher in the measures, which would be revealed by careful prospecting. The country is very sparsely inhabited by a few natives to whom the coal is of no use. They, therefore, attach no more value to it than to the other rocks of the mountains, and have accordingly made no attempt to uncover the coal. Exposures, therefore, are few.

As to the quality of the coal in this northern region, we refer to the Analysis No. 1 below. We may say that the sample from which this analysis was made consisted of a number of pieces from all the openings in Veins No. 2 and No. 3 at Los Baños. These were the only ones which furnished proper samples for analysis, and while we had no opportunity to make a proper sample from the total height of the bed, still, this analysis will probably furnish a fair criterion in which to judge the quality of this coal.

We would call attention to the high specific gravity of this coal. The anthracite coal of the Wyoming and Lackawanna Valleys in Pennsylvania would average about 1·5

specific gravity, whereas this coal, as determined by Mr. McCreath, and also as determined by us, runs from 1·62 to 1·65 specific gravity, which is a very good feature, indeed. We regard the anthracite of this northern coal field, as far as we have been able to judge, equal to the average anthracite of Pennsylvania, as will be shown by Analysis No. 1 following, by Mr. McCreath, of Harrisburg.

ANALYSIS No. 1.

| | |
|---|---|
| Water | 1·450 |
| Volatile matter | 5·633 |
| Fixed carbon | 83·620 |
| Sulphur | ·554 |
| Ash | 8·743 |
| | 100·000 |
| Specific gravity | 1·62 |

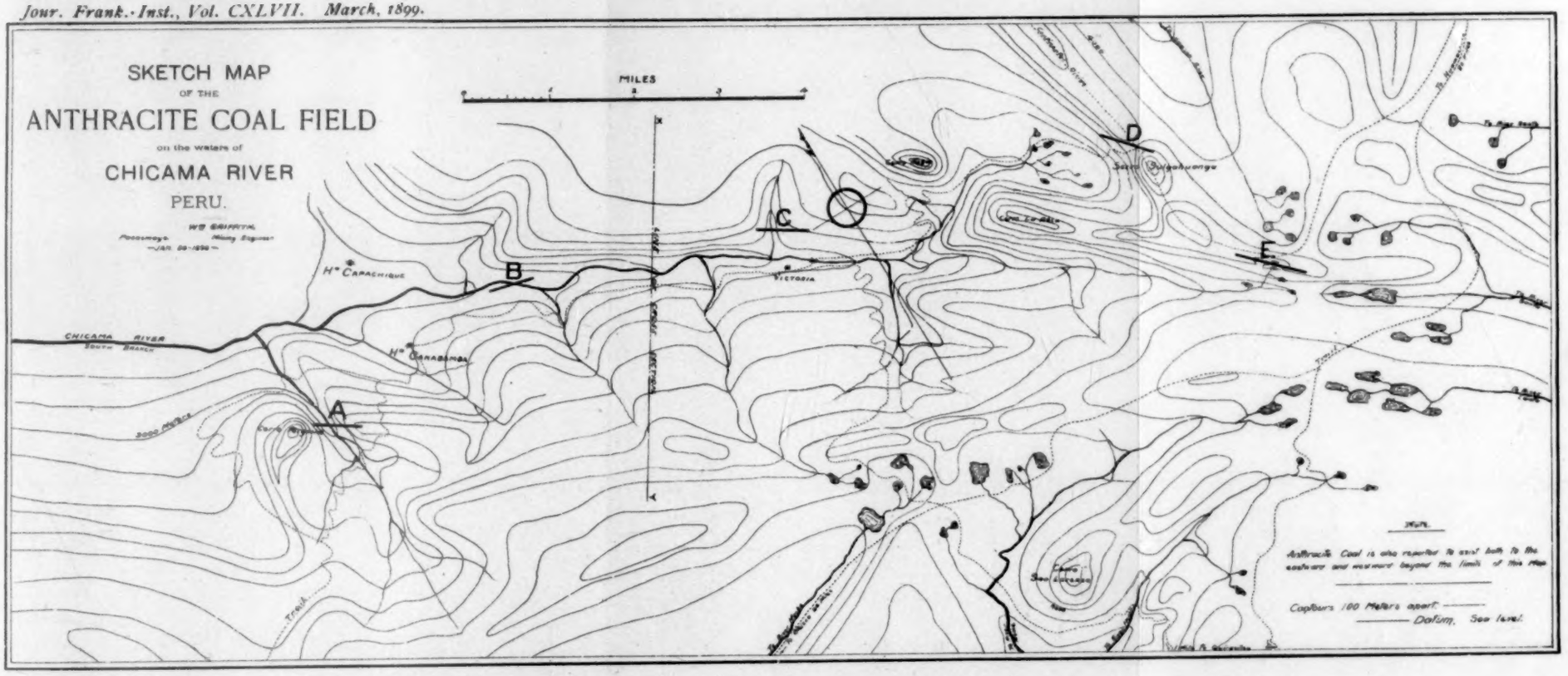
THE SOUTHERN FIELD.

The second anthracite field visited, which we have previously called the Southern Field, may be approached by the trail leading inland from the city of Trujillo on the Pacific coast, about 60 miles southward from Pacasmayo. This trail passes up the cañon of the river Moche to the town of Otuzco, thence over a summit to the head waters of the south branch of the Chicama River in the Department of Libertad. It is in this latter locality along the upper Chicama that we find the coal. The waters of this stream flow to the Pacific at a point about 15 miles northward from Trujillo, and the coal fields are about 100 miles southward from the northern field just described and about 80 miles inland from Trujillo and a little more than 100 miles from Pacasmayo. Our trail first enters the field in the valley of the stream at about 9,000 feet elevation on the westerly slope of the Andes, and we are able to follow the measures for 15 or 20 miles, and probably much further to the southeastward, to the summit of the Continental Divide, or even as far as the head waters of the Santa River, which flows into the Pacific near the bay of Chimbote. The south branch of the Chicama is here a very rapid mountain torrent, flowing in a deep valley with sloping sides, which rise

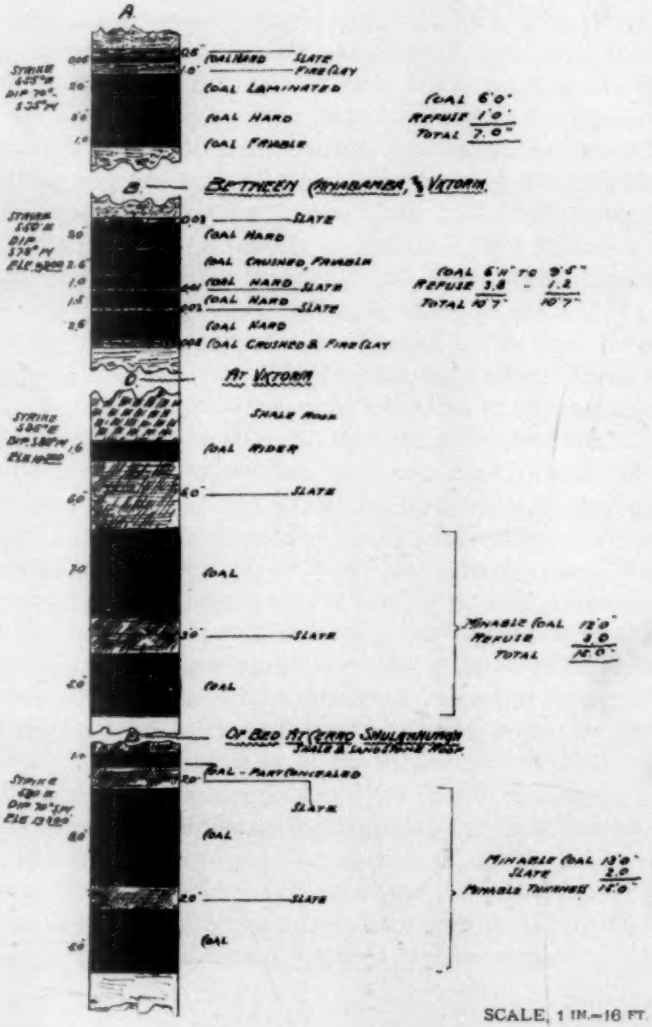
to the height of about 13,000 feet, and it is in these mountains, partly on both sides, but mostly on the northern side, that the coal is found. The strike of the measures is north 50° west, the same as the course of the stream; the average dip of the rocks is very steep, being 70° to 80° in a southwesterly direction. The coal-bearing rocks here seem to be the same sort of hard altered sandstone in which we find the coal in the northern field, although the formation is more distorted by volcanic action, which is quite evident and prominent in some portions of this southern field. At the point where we entered the valley the coal-bearing rocks were to be found on both sides, but further to the southeastward, that is, up stream, they occupied the flank of the mountain on the northerly side of the valley, which was more precipitous than the opposite side, which seemed to be composed mostly of a softer formation, consisting of dark slates and shales regularly stratified, containing numerous shells of recent age, although we saw no limestone in this vicinity. We were unable to trace the existence of any regularly formed coal basin; the dip seemed to be all one way—southwesterly, and over the mountain to the southwestward of the coal measures the formation changed to the eruptive rock so common in this portion of the Andes, thus apparently breaking off the continuity of these measures to the southwestward. The coal beds in this neighborhood are quite large and very prominent, and owing to the steepness of the dip, the soft material of the outcrops have been eroded by the continual rains of the wet season, thus forming long troughs or depressions, which may be easily traced. The beds seem to extend with a fair degree of continuity for a distance of at least 15 or 20 miles, and in all probability much farther. We had information of coal beds being uncovered several miles to the westward and over the divide to the southeastward, beyond the limits of the territory examined; there were numerous exposures to be seen, particularly on the northerly side of the valley, many of which had been opened by the natives, who use the coal for blacksmithing, and so on. These openings were mostly confined to what appeared to be one or two

mammoth coal beds opened at various points. The first of these is situated in the mountain side of the southerly side of the valley at an elevation of about 10,000 feet above tide, on a branch of the main stream. At this point there are two or three beds visible, one of which was being mined and the coal transported several miles to a silver works, where it is used for roasting silver ore. Other smaller beds, about 3 feet in thickness, were located about 100 feet apart lower down in the measures. The principal bed, however, a measured section of which is given on *Plate 3*, section *A*, seemed to be a very fine seam. This bed of coal, about 6 feet thick, occurred lying between well-defined walls of hard white sandstone. The walls were separated about 15 feet apart, and the erosion of the softer measures contained between them formed a great ditch or trough, which could be plainly seen ascending the mountain several hundred feet, and also descending and crossing the branch cañon, though the seam was evidently much thinner near the bed of the stream. This opening was about 500 feet up the side of the cañon. This same bed was opened at another point higher on the mountain side, which was closed at the time of our visit. The coal from this latter opening was described to us as being very soft and friable, and was dug out with a shovel and carried on mule backs to the silver works, several leagues away, where it was mixed with a percentage of clay, made into balls, and, after drying, was used in this form for roasting silver ore. This mine was said to have been driven 300 or 400 feet into the mountain side. It was near the top of the mountain, which was, possibly, the reason at this point for the crushed or disintegrated coal, or, as we would call it in the anthracite region, a dirt fault. These dirt faults are quite common in the Schuylkill region of Pennsylvania, and are expected and met and overcome in the ordinary course of mining in that field.

The second important opening was about 3 miles further up the stream, close to the level of the creek. Here a fine bed of coal 10 feet thick was found, a measured section of which is shown on *Plate 3*, section *B*. The elevation of this coal opening was about 9,300 feet, with a strike about 50°


SKETCH MAP
OF THE
ANTHRACITE COAL FIELD
on the waters of
CHICAMA RIVER
PERU.
MILES
A
B
C
D
E
Cerro San Antonio
Note.
Anthracite Coal is also reported to exist both to the eastward and westward beyond the limits of this Map
Contours 100 Meters apart.
Datum, Sea level

# SECTIONS NEAR CANABAMBA AND VICTORIA ON SOUTH BRANCH CHICAMA RIVER.



southeast, dipping 73° to the southwestward. This bed is a very fine one, being nearly all pure coal, the only poor feature being a stratum of soft or crushed coal 2½ feet thick. This, however, may change to firm coal at other parts of the bed. This fact, however, could only be proved by the actual course of mining. Benches of crushed coal are quite common in the Schuylkill region of Pennsylvania, where, even including this crushed stratum, this bed would be considered a very economical and profitable bed to work. As in the other cases noted in this coal field, the beds were enclosed by walls of hard sandstone, smooth and straight, and the ditch or trough formed between these walls at the outcrop can be traced ascending the mountain on the other side of the creek to the southeastward. Also smaller depressions indicating the presence of other coal beds of various thicknesses parallel to and both overlying and underlying this mammoth bed, can be readily traced. About 3 miles further up the stream another opening has been made into this mammoth bed. At this point is the lixiviation plant, known as the Victoria Silver Works. The ore is here roasted by means of the anthracite coal taken from this seam. A very primitive gas generator has been constructed and the gas is used to roast the pulverized silver ore. This coal opening has been worked for some time, the bed is evidently very large and fine, as can be seen from Section *C*, on *Plate 3*. It had, unfortunately, owing to the unworkmanlike manner of mining, caved in three days before the date of our visit; so that while we were unable to take a measured section of the bed the evidences of a very large, fine coal bed at this point were unmistakable. We were allowed to copy the measurements shown in Section *C*, from the report of an English engineer who had examined the silver works at Victoria. This opening is at an elevation of 10,300 feet; also in the side of a steep cañon cut in the mountain by a small creek, which flows at right angles to the strike of the seam, and empties into the Chicama, a short distance away. As far as the eye could reach on either side of the coal bed, the location of the outcrop might be easily noted by the immense gulley formed by the erosion of the outcrop. In the

sides of this cañon the outcrops of other beds could also be noted, located 100 feet more or less apart, underlying the mammoth seam. The hills on both sides of the cañon are about 700 feet higher than the drift level, and the drift mouth was about 300 feet or thereabouts above the level of the Chicama. Several other exposures or openings into this seam were noted further to the southeastward at various points, separated several miles apart. One of these is located about 5 miles from Victoria on the crest of the Continental Divide, elevated about 13,000 feet above the ocean. The large outcrop gives evidence of a remarkably fine bed of anthracite. It can be plainly seen enclosed between high walls of quartzo-sandstone, which project 20 or 30 feet above the coal and form, as in other cases, an immense ditch 40 feet in width. The coal occurs in the soft measures between these sandstones, which extend for 2,000 or 3,000 feet along the mountain side. At the time of our visit some natives were loading the coal on donkeys for transportation to a distant village for blacksmith purposes. The full section of this bed could not be measured, as part of it was concealed, but the portion exposed to view, about 18 feet, is shown in Section *D* on *Plate 3*, and discloses a remarkably fine bed of anthracite coal. The openings referred to, to the southeastward to this point, which were not sufficiently enlarged to enable us to take the measurements of the sections, disclosed, however, the clear, clean anthracite coal, giving proof of the economical thickness and workable quality of the seams. As stated before, this same series of coal-bearing rocks, probably extend further to the southeast, as has been reported. We know, however, that coal dirt or blossom is brought from what was represented to us as a large coal bed located beyond the limits of our search, to the silver mining town of Quiravilca, and there made into balls by mixing with clay, for domestic use. Samples of coal were also shown to us from the northwestward extension of this same field, taken from another branch of the Chicama River, giving evidence of the extension to the northwestward of this coal field, far beyond the limits of the territory visited. As to the uniformity and continuity of these coal seams we will

say we consider the measures here to be much more disturbed through volcanic action than in the northern field. Nevertheless, we believe that the evidences of continuity are sufficient to warrant the conclusion that an immense body of coal exists in this vicinity, which can be economically mined, and much of it above water level, even within the territory described; while the same measures unquestionably extend in both directions far beyond these limits. Samples of coal were taken from the openings mentioned, an average sample of which gave the Analysis No. 2 following, also by Mr. McCreath:

ANALYSIS NO. 2.

| | |
|---|---|
| Water | 1·596 |
| Volatile matter | 3·030 |
| Fixed carbon | 90·906 |
| Sulphur | ·652 |
| Ash | 3·816 |
| | 100·000 |
| Specific gravity | 1·67 |

From this analysis we should judge that the coals in this region are of unusual purity and excellent quality. For sake of comparison we give here an average analysis of Pennsylvania anthracite:

NO. 3—PENNSYLVANIA ANTHRACITE, AVERAGE OF 31 ANALYSES.

| | |
|---|---|
| Water | 3·277 |
| Volatile matter | 4·317 |
| Fixed carbon | 83·294 |
| Sulphur | ·600 |
| Ash | 8·514 |
| | 100·000 |
| Specific gravity | 1·59 |

It is impossible to make any reliable estimate as to the depth to which these coal seams extend. As stated above, they dip into the ground at an angle of about 70° and extend along the strike from the northeast to southwest from 15 to 30 miles or more. Owing to this dip, and the fact that the soft measures have been washed away from the outcrops it is much easier to open into the coal and follow the

outcropping than in the northern field. And while the coal openings are more numerous and much more coal actually visible to the eye in the southern field, it does not necessarily follow that there is more minable coal here, because owing to the different mode of disposition of the coal, the outcrops in the northern district are more or less covered with debris and vegetation, so that they are not visible unless exploration is especially made for the purpose of uncovering them. And the beds are so disposed that they may be more cheaply mined.

We made a collection of the fossil plants which are to be found in the slates accompanying the coal beds, which have been submitted to experts of the Smithsonian Institute at Washington and elsewhere, and they have been able to state, perhaps, definitely, as to the geological horizon of the Peruvian coals. From the results of their investigations there would seem to be no doubt that these measures are of more recent age than the anthracite coals of the carboniferous measures of Pennsylvania or the Triassic coals of Richmond, Va., and are probably of Jurassic age and somewhat older than the anthracite and bituminous coals of the cretaceous formation in Colorado. Their position being thus mid-way, as it were, between formations containing economical coal beds of well-known extent and continuity, would seem to be favorable for an extensive deposit of coal in the region under consideration. In Colorado the anthracite coals are known to be more or less local in extent; that is to say, the bituminous seams are found overlying or underlying the seams of anthracite, in the same formation, while the same bed of coal may be anthracite in one place and bituminous in another. This is doubtless caused by the fact that the heat required to change the bituminous coal to anthracite, which was probably derived from the existence of eruptive rock near the coal seam, was more or less local in its effects, and apparently more intense in some places than in others; and the bituminous coal which in one place was undisturbed, in another part of the coal measures was converted into anthracite. We think we are prepared to say that this condition of affairs does not exist in the limits of this territory.

Throughout our travels we have noticed the unmistakable evidence of an intense heating of the rock formation in all portions of the Andes Mountains. The sandstones containing the coal, wherever we have noted their existence, have been unmistakably heated to an extreme degree, and there were absolutely no evidences of the existence of bituminous coal anywhere within these measures, so far as we have been able to ascertain. We regard the lignitic coal of Yanacancha and elsewhere as a deposit of a more recent age, and while we understand that coal of various kinds exists in other portions of the same region, not examined by us, we think it extremely doubtful that in any of these places will be found bituminous coal in the rocks of the same age which contain anthracite. We are, therefore, of the opinion that the anthracite coals of these fields will be found uniform in quality throughout the whole extent of the measures in which they exist.

### HUAMACHUCO BASIN.

Our travels were continued to the ancient town of Huamachuco, on the eastern slope of the Andes. This town is located in the bottom of a wide, deep valley, evidently composed of the soft measures underlying the coal-bearing rocks. Capping the mountain on either side of this valley, the measures have the same appearance at a distance as those which covered the hills in the northern field described. Abundant rumors came to our attention of the existence of coal seams in the mountains adjacent to Huamachuco. No attempt was made to examine them, as they were evidently more or less inaccessible, and our time was limited. However, it is probable that economical coal beds exist here on the eastern side of the continental divide. The citizens of Huamachuco use the coal blossom from the anthracite seams of the valley for domestic purposes by mixing with clay, as before described. It is questionable, however, whether the beds near the town from which this blossom is secured are of economical thickness. It is highly probable that if proper time was given to exploration in this northern portion of Peru, other coal areas would be found

within the region covered by this paper, and which are not known at present. From what has gone before, however, it would seem conclusive that there exists in the Andes Mountains of northern Peru a vast wealth of anthracite coal awaiting development for the supply of the coal market of the western coast of South America or along the Amazon River system.

## THE SMOKE NUISANCE WITH SPECIAL REFERENCE TO THE CONDITIONS PREVAILING IN PHILADELPHIA.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts.*]

[No. 1963.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 12, 1898.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, to which was referred a communication of the Board of Health of the City of Philadelphia, requesting the co-operation of the Franklin Institute in reference to the proper regulation of the smoke nuisance in the City of Philadelphia, respectfully reports as follows:

The Franklin Institute has held two meetings devoted especially to the consideration of the subject of the abatement of the smoke nuisance from a scientific standpoint, at which meetings numerous engineers discussed the matter. These proceedings were published in full in the *Journal* of the Institute for June and July, 1897. In response to a general request, the discussion was resumed in September and October, when the various appliances in use for smoke prevention were illustrated and explained by many manufacturers. These data were printed in full in the *Journal* for January and February, 1898.

The Board of Managers of the Institute reported the following preamble and resolutions, which were adopted at the stated meeting of the Institute on September 15, 1897:

"WHEREAS, The Board of Health of the City of Philadelphia has requested the Franklin Institute to discuss the question of smoke prevention, and to offer practical suggestions relative thereto; and,

"WHEREAS, The use of bituminous coal for fuel is increasing in this city and is likely so to continue in the future; and,

"WHEREAS, It appears from testimony presented to the Institute that it is practicable to burn bituminous coal in suitably constructed furnaces without creating a smoke nuisance; therefore, be it

"*Resolved*, That it is the opinion of the Institute that the continuous or frequent discharge of dense black smoke from furnaces of stationary boilers is avoidable, and should not be permitted within the city limits.

"*Resolved*, That the emission of smoke from locomotives and furnaces other than those of stationary boilers might be greatly reduced if the co-operation of firemen and employers was enlisted with an earnest intention to abate the nuisance, and more especially could the railway companies be induced to use anthracite coal or coke in the furnaces of the locomotives used for local service in the train-yards within the city limits.

"*Resolved*, That a copy of these resolutions be sent to the Mayor, to the President of the Board of Health and to the Presidents of City Councils."

The sub-committee held numerous meetings, discussing the matter with the late Dr. Ford, President of the Board of Health, and Mr. Theo. N. Ely of the Pennsylvania Railroad.

After a careful consideration of all the data obtainable, the committee recommends that the following conclusions be referred to the Board of Managers for embodiment in the draft of an Ordinance to be transmitted to the Board of Health:

(1) The continuous discharge of dense black smoke from

stationary boilers using bituminous coal can be prevented by the use of appliances now well known.

(2) The discharge of dense smoke from locomotives using bituminous coal has not been shown to be preventable, and large volumes of smoke will probably continue to be produced from these boilers. Much of the nuisance would be abated should all drilling and shifting engines be required to burn smokeless fuel.

(3) The burning of soft coal in private dwellings produces smoke, but as the amount of soft coal so burned in this city is small, and is not likely to increase largely, the Committee does not regard this phase of the question as serious. Moreover, it has thus far not been found practicable to apply any mechanical device to prevent the formation of smoke in such cases.

It is the opinion of the Committee that a suitable smoke ordinance embodying the two suggestions herein, is not only desirable, but necessary, in order to prevent the gradual growth of a smoke nuisance; it is believed, moreover, that such an ordinance would not entail undue hardship upon any interests, and would not necessarily involve the city in much expense if put into effect before the evil complained of by the Board of Health shall have attained large proportions. Prevention in this case is better than cure.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, May 4, 1898.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

L. F. RONDINELLA,
*Chairman Committee on Science and the Arts.*

[The sub-committee which conducted this investigation was composed of Prof. H. W. Spangler, Mr. A. E. Outerbridge, Jr., Dr. Coleman Sellers, Mr. Wm. M. Barr, Mr. John Birkinbine.]

APPENDIX.

The Committee on Science and the Arts, having been charged with the duty of framing an Ordinance embodying the foregoing conclusions, to be submitted to the Board of Health, as expressive of the views of the Franklin

Institute, presented the following draft, which was approved by the Board of Managers, and ordered to be transmitted to the Board of Health; viz.:

A PROPOSED ORDINANCE to prohibit the frequent emission of opaque smoke from chimneys of boiler furnaces and from smoke-stacks of shifting locomotive engines, and declaring the same a public nuisance subject to penalty.

SECTION 1. The Select and Common Councils of the City of Philadelphia do ordain: The frequent emission of opaque smoke from any chimney or smoke-stack of any boiler furnace within the corporate limits of the City of Philadelphia, shall be deemed, and is hereby declared to be, a public nuisance, and is hereby prohibited.

SEC. 2. The frequent emission of opaque smoke from the smoke-stack of any shifting locomotive engine, within the corporate limits of the City of Philadelphia, shall be deemed, and is hereby declared to be, a public nuisance, and is hereby prohibited.

SEC. 3. The discharge of opaque smoke for more than three minutes in any one hour, and repeated in subsequent hours, shall constitute frequent emission within the meaning of this ordinance.

SEC. 4. Any person or corporation being the owner, agent, lessee, trustee or manager of any boiler or shifting locomotive engine, and any person or persons employed in operating any such boiler or shifting locomotive engine, who shall cause or permit opaque smoke to be frequently emitted from the chimney of such boiler furnace or from the smoke-stack of such shifting locomotive engine, within the corporate limits of the City of Philadelphia, shall be guilty of creating a public nuisance, and shall, for such offense, on conviction thereof, be liable to a penalty of $10 for the first offense, $25 for the second offense, and $50 for each succeeding offense, to be recovered in the manner that penalties for breaches of city ordinances are now by law recoverable, unless the offender can satisfactorily demonstrate that the smoke emitted from the chimneys or stacks under his control is practically unavoidable and is determined by the necessities of his business which cannot be remedied.

SEC. 5. It shall be the duty of the Director of the Department of Public Safety, of his own motion or upon complaint in writing of any citizen, to enforce the provisions of this ordinance, and to make complaint and cause to be prosecuted all persons or corporations violating the same.

SEC. 6. This ordinance shall go into effect sixty days after its approval.

## NOTES AND COMMENTS.

### THE UNITED STATES REPAIR SHIP "VULCAN."

The following extract, from a recent report of Commodore G. W. Melville, Chief of Bureau of Steam Engineering, U. S. Navy, referring to the equipment of this unique craft and her service, will be of interest:

"In the last report, attention was called to the desirability of making such preparation for the fitting out of a vessel which would be a floating repair shop as would enable the work to be done with great rapidity when

needed. Immediately, on prospect of war, the Bureau again brought this matter to the Department's attention, and the steamer 'Chatham' was bought, set aside for this purpose and named the 'Vulcan.' The work of installing the machine tools, cupola, forges, brass furnaces, etc., was pushed as rapidly as possible, as well as the selection of a force of skilled mechanics. A large and well-chosen outfit of stores of all kinds was also supplied.

"The 'Vulcan' arrived at Guantanamo on July 1st, and proved of the highest usefulness to the fleet, making repairs of all kinds and furnishing much needed supplies to every department of nearly every vessel. At the end of August reports from her officers showed that she had made repairs to sixty-three ships and had supplied stores to sixty. Her unusual facilities and the large number of skilled mechanics on board (about 100) enabled her to make repairs of all kinds, including hull work, gun mounts, dynamos, main steam pipes, main piston rods (for small ships), brass castings without end and iron castings in considerable quantity. This last is especially interesting as the first instance of the successful use of a cupola on shipboard."

At a special meeting of the Mechanical and Engineering Section of the Institute, Prof. Wm. S. Aldrich, late Assistant Engineer, U. S. N., who served on the "Vulcan" during her service with Admiral Sampson's fleet, gave a detailed description of the ship and her equipment, and narrated many instances, showing how indispensable an auxiliary vessel of this class must be in the naval operations of the future. W.

## MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

A Teachers' Reception was given last week in the new Pierce Building on Trinity Place. Invitations were sent to the school Principals and Superintendents, Institute graduates teaching in Massachusetts and members of teachers' associations in Physics, Chemistry and Biology.

About eighty persons attended, including, among others, Dr. Tetlow, Mr. Collar and Mr. Parmenter, of the Boston schools; Superintendent Aldrich, of Newton; Superintendent Boyden, of Bridgewater Normal School; Superintendent Cogswell, Dr. Huling and Mr. Bradbury, of Cambridge; Mr. Whitcomb, of Somerville; Superintendent Gay, of Malden; Mr. Holt, of Arlington; Mr. Briggs, of Chelsea; Mr. Jackson, of Lynn; Mr. Lovering, of Winchester; Mr. Parker, of Brockton; Mr. Kelley, of Haverhill; Mr. Amen, of Exeter; Mr. Curtis, of the Hale School; Mr. Horne, of Dummer Academy; and Mr. Shaw, of Worcester Military Academy. The Corporation was represented by the President, Dr. Williams, Mr. Wigglesworth, Mr. Wheeler, Mr. Lothrop, Mr. Gaffield and Mr. Munroe.

The guests were received by members of the Corporation and Faculty. Lunch was followed by an address by President Crafts. He discussed the relations between the secondary schools and the institute, and emphasized the privilege and duty of the secondary schools in discovering aptitudes in students, not merely directing students where chance, or parents' or teachers' preferences pointed.

Professor Chandler followed with a talk on the design and construction of school houses, showing by stereopticon slides and charts how the architects are endeavoring to meet the requirements of the educators.

Visits were then made by the guests to the various departments of the new building.

Mr. H. F. J. Porter, of the Bethlehem Iron Company, lectured to a large audience at the five hundred and twenty-first meeting of the Society of Arts last Thursday evening.

His subject was "Modern Forging," and he presented in a very interesting way, with numerous illustrations by the stereopticon, the methods in vogue at the Bethlehem Iron Works of forging such articles as hollow and solid shafts, dynamo field rings, guns, armor plate. Views were shown of the hollow shafts of the "Oregon," and of the "Brooklyn," made at these works. Defects in the old methods of forging and the steps leading to the present methods were well explained. W.

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## A NOVEL PUMPING ENGINE

The Holst pumping engine, devised by Mr. C. P. Holst, of Amsterdam, was designed, primarily to avoid the repeated stopping and starting of any part of the water, and thus to do away with the difficulties due to inertia.

The water flows in one direction only. In its passage from the inlet to the outlet it passes through four valves, which are attached to and move with the piston rods. At any instant three of these valves are open, allowing the water to pass through, while the fourth is closed, and, acting as a piston, takes all the work of pushing the water through the pump. This it continues to do for one-quarter of a revolution of the fly-wheel, when it becomes an open valve, and one of the others becomes a piston. W.

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## A NEW APPLICATION OF THE ROENTGEN RAYS.

The latest practical application of the Roentgen rays is to the testing of coal. It is stated that carbon in all its forms is quite transparent to these rays, while the substances—silica and the silicates—which constitute the ash or incombustible constituent, are opaque to them.

By placing a lump of coal between a Crookes tube and a fluorescent screen, it is stated that all the slag and clinker-forming portions of the fuel can be detected. M. Cuoriot, on whose authority this statement is made, has tested in this manner anthracite and bituminous coal, lignite, coke and artificially prepared briquettes. In these tests, rough lumps of coal, 1¼ inches to 2 inches thick may be used, with an exposure of five minutes, and with a coil giving a 10-inch spark. W.

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## AN ELECTRICALLY HEATED FURNACE FOR POTTERY.

The London *Electrical Review* is authority for the statement that an English firm has developed an electric process for the production of ceramic wares which yields very superior results. Briefly described, it consists in the employment of photography for the production of the designs, and an electric furnace of special design for burning in the designs, the photographs being covered with a special glaze. The excellence of the product is stated to be due chiefly to the method of burning, the electric furnace permitting of being kept under complete control.

## AN IMPROVED METHOD OF MAKING STEEL CASTINGS.

The merits of the Walrand-Legenisel steel process were made the subject of discussion at the last meeting of the American Institute of Mining Engineers. This process practically supplements the Bessemer process in such a way as to permit the making of castings directly from the converter. Its essential feature consists in the addition of ferro-silicon (containing from 10 to 12 per cent. of silicon) to the charge in the converter, when the flame drop takes place, and then making an after-blow. The oxidation of the silicon which takes place generates a large amount of heat, which is imparted to the metal—as the combustion product is not volatile—and the consequence is that the steel becomes strongly superheated. The metal is very fluid, produces castings quite free from blow-holes, and permits the making of intricate castings down to a fraction of a pound in weight.

By the usual methods in vogue, the production of sound castings, especially those of small size, has always been attended with great difficulties. The high degree of superheating attained in the new method appears to obviate this difficulty. The new process is successfully employed at large works in France and Germany, and in at least one large works in the United States.

W.

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## CAPITAL PUNISHMENT BY ELECTRICITY ADOPTED IN MASSACHUSETTS.

The State of Massachusetts will hereafter put its condemned criminals to death by the electric current, instead of by the hangman's noose. The Governor of that State lately signed a bill of the legislature making provision for the change.

W.

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## USEFUL ALLOYS OF ALUMINUM.

With the considerable cheapening of the cost of aluminum, there has naturally followed a considerable extension of its applications in the arts. The physical properties of the pure metal, however, more especially its low tensile strength, and the difficulty of making soldered joints with it, have now come to be recognized as imposing considerable limitations to its usefulness.

But, although the pure metal has undesirable qualities, it is most fortunate for the future development of the aluminum industry, that it is capable of forming alloys that possess most valuable properties.

Thus, the alloy of copper with from 10 to 11 per cent. aluminum is one of the strongest known, its tensile strength ranging from 80,000 to 90,000 pounds per square inch. It also has a high elastic limit, but a low percentage of elongation (5 per cent. in 1 inch). The presence of silicon increases its strength and hardness, but decreases its ductility. Of the brasses the one containing 3·50 per cent. aluminum, 33·3 per cent. zinc, the rest being copper, is the best and strongest, having a tensile strength of from 75,000 to 85,000 pounds per square inch.

The addition to aluminum of a few per cent. of certain metals (such as nickel, tungsten or silver) likewise exerts a most beneficial influence in modifying the undesirable properties of the metal.

The production of such alloys, suited for a variety of special uses, has been the subject of extended investigation by the manufacturers of the metal, and they have been conspicuously successful. W.

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## MORE ABOUT "RUBBER FROM CORN."

The brief notices in the technical papers referring to the possibility of utilizing the refuse material of the glucose factories, amounting to about 5 per cent. of the raw material, have recently been supplemented by an interesting communication on the subject in the Chicago *Times*, purporting to give an account of experiments that have been secretly conducted in that city for the past year by the chemists of a large glucose company.

According to the writer of the article in question, the process of manufacture is now so far perfected that the product may, within a few months, be ready for the market.

The following details will be of interest:

"Corn rubber has almost exactly the appearance of the ordinary reddish brown india-rubber. The process of manufacturing is not perfect enough, however, to make it resist heat as well as india-rubber. This has offered the greatest difficulties to the chemists, who are now working to remedy this defect. The oil of corn, from which principally the rubber is made by some secret process, does not oxidize readily, and those who are working on the corn rubber declare this will be an enormous advantage for the new product. Articles manufactured from it will always remain pliable and not crack. Contrary to reports, this new product has not yet been put on the market. It is intended to go on with its experiments till the success of the new substance is assured, and then to go into its manufacture on an immense scale.

"The corn-oil from which the rubber is made, comes from the germ of the corn and not from the hull. The starchy and glutinous portions of the kernel are used in making glucose and starch, while the corn-oil, heretofore, according to the refiners, has been practically useless. The five refineries of the trust have used 21,000,000 bushels of corn in the last ten months, of which about 5 per cent. was refuse. Though forty different products are made by the company, still 5 per cent. was practically waste. By utilizing this waste material in making the new product it is calculated that corn rubber can be sold at 6 cents a pound, 2 cents of which will be clear profit. The corn rubber, it is said, will be adapted to nearly all the uses that ordinary rubber is capable of—from bicycle tires to linoleum. The more refined uses to which the rubber is put, however, will still be a closed field, for the composition of corn rubber will prevent its substitution for india-rubber for scientific uses."

The article proceeds to state that the new product may be advantageously mixed with Para rubber, producing a cheaper article of substantially the same quality for ordinary service, as the genuine rubber. W.

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## SEEING AT A DISTANCE BY ELECTRICITY.

Much interest has lately been aroused over the alleged discovery by Szczepanik, a Polish inventor, of a method by which vision at a distance is rendered

practicable. The apparatus by which this is to be accomplished, is called the "Telectroscope." The complete details of this invention have thus far not been disclosed, but the *Scientific American* supplement has lately published an article giving the present state of knowledge on the subject of electrical vision, from which the following statements are taken :

As may have been anticipated, the fundamental principle involved in all the devices that have been proposed for this purpose is the variation in the electrical conductivity of selenium under the influence of light of varying intensity. To demonstrate this property of selenium, the simplest plan is to include a selenium cell in a telephone circuit, when a sharp click will occur in the receiver every time that a bright beam of light is allowed to fall upon the selenium.

Coming to the alleged discovery of the expert above named, it is said to consist in brief "in allowing the rays emanating from the object to fall upon a cell of selenium. Electric impulses will be produced in the selenium, whose intensity depends upon the brightness of the rays falling upon the cell. These impulses, being conducted to a distant receiving station, are there transformed again into light. The rays falling upon the selenium are first separated into points of light by oscillating mirrors in the transmitting station. Similar mirrors in the receiving station vibrate synchronously with the mirrors of the transmitting station, and reproduce the image of the object."

"The circumstance that the retina of the eye is sensitive to a light impression for a very minute, though definite, interval of time after the light has ceased to affect it, a peculiarity called by physicists the 'persistence of vision,' explains the fact that the rapid vibrations of the mirrors are perceived simultaneously.

"A spark on the end of a stick, when swung around in a circle, produces the impression of a ring of light. In an exactly similar manner, the rapidly succeeding points of light falling from the object upon the mirrors, produces, apparently, the image of the original object.

"The question then naturally arises: Is it possible to oscillate the mirrors with sufficient rapidity to produce a series of points, which, following one another with great rapidity, will cause a picture of the object to be produced?

"The mirrors are arranged in pairs at right angles, as regards their vibrations, and hence the number of points projected on the selenium in the transmitter will be equal to the product of the number of oscillations performed by each of them. If, for example, each mirror swings on its axis only 100 times a second, then 10,000 points of light will, in a like period, fall on the selenium and be transmitted. As a matter of fact, these may number hundreds of thousands, or even millions. So rapid are the oscillations of the mirrors that the tenth part of a second is sufficient to analyze the image of an object in the transmitter, and to render it visible at the receiving station. It is therefore, possible to transmit a continuous action, such as a theatre performance, over the wires of the telectroscope, since the pictures received follow one another so rapidly as to produce the impression of a moving image, just as the numerous separate pictures of a chromo photographic apparatus reproduce past actions."

It is stated in the article from which the foregoing account has been abstracted, that it is the inventor's intention to withhold full details of his

system and apparatus until the same shall be shown in operation at the World's Fair in Paris to be held in 1900.

Apropos to this, it is worthy of notice that this inventor has made the same reservation about disclosing the details of another alleged invention, no less remarkable in character than this one, and which also was recently the theme of much discussion in the technical and newspaper press. It would be quite as well, under these peculiar circumstances for the public to await these promised revelations and meantime to do as the gentleman with the unpronounceable name has done, accept his statements with reservation. All that can safely be said of this particular invention is that it is possible in theory, and plausible so far as the details have been disclosed. W.

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### NEW USES FOR ALUMINUM.

It is reported that experiments have been carried on at the United States Mint in Philadelphia for nearly a year with the view of ascertaining the fitness of aluminum for minor coins. Some 10,000 blanks of the size of the nickel (5-cent piece) have been delivered at the mint for this purpose. It may be mentioned that Congress some time ago appointed a commission of experts to investigate and report upon this subject, and the experiments above referred to are being carried on under the direction of its members.

In the source from which the foregoing information is taken, no allusion is made to whether the blanks are of pure aluminum or of aluminum alloyed with a hardening metal. The pure metal would in all likelihood prove objectionable in service as a coin metal.

A current item of news relates to the interesting fact that one of the great electric companies, which is engaged in the equipment of a large electric power transmission plant in the State of Washington, has ordered 200,000 pounds of ¼-inch aluminum wire for carrying the current. This is practically a new field for the aluminum industry, and promises a great expansion in the near future. W.

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# Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, February 15, 1899.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 15, 1899.

MR. THEO. D. RAND, Vice-President, in the chair.

Present, 92 members and visitors.

Additions to membership since last month, 64.

The report of the Actuary embraced the following important information:

"* * * Upon the recommendation of the Committee on Sectional Arrangements, the Board of Managers has authorized the formation of a 'Physical and Astronomical Section,' of the Institute, upon the petition of the following-named members, whose names have, in accordance with the By-Laws, been recorded as the founders of the Section; to wit:

"Prof. E. J. Houston, Philadelphia, Pa.
"Prof. Geo. A. Hoadley, Swarthmore, Pa.
"Prof. E. A. Partridge, Central Manual Training School, Philadelphia.
"Prof. A. S. Mackenzie, Bryn Mawr College, Bryn Mawr, Pa.
"Prof. Geo. F. Stradling, Northeast Manual Training School, Philadelphia.
"Dr. A. E. Kennelly, Crozer Building, Philadelphia.
"Prof. Luigi d'Auria, 3810 Locust Street, Philadelphia.
"Prof. Thos. E. McDermott, Catholic High School, Philadelphia.
"Prof. Eugene C. Foster, Temple College, Philadelphia.
"Prof. Jesse Pawling, Jr., Central High School, Philadelphia.
"Prof. Harvey Newcomer, 4116 Spruce Street, Philadelphia.
"Prof. Richard Zeckwer, Philadelphia Musical Academy, Philadelphia.
"Prof. G. B. M. Zerr, Central High School, Chester, Pa.
"Prof. Eric Doolittle, University of Pennsylvania, Philadelphia.
"Prof. J. M. Moyer, Northeast Manual Training School, Philadelphia.
"Prof. L. T. Edwards, Haverford, Pa.
"Prof. Geo. H. Hallett, University of Pennsylvania, Philadelphia.
"Mr. Paul R. Heyl, Reading, Pa.

"In addition, I am directed by the Board, to report the following resolutions, adopted at its stated meeting, held Wednesday, February 8th, 1899.

> "'*Resolved*, That the Board of Managers requests the Franklin Institute to pass the following resolution:
> "'*Resolved*, That the Franklin Institute, for the promotion of the mechanic arts, hereby authorizes the President and Secretary of the said Institute to make, sign, seal, execute and deliver unto the Trustees of the said Institute, a deed for the real estate, No. 1543 Page Street, in the city of Philadelphia, devised to the said Institute by the will of M. Carey Lea.'

"I have to report further, that the Board being informed of the introduction of a bill into the Legislature of the Commonwealth at Harrisburg, making an appropriation of $200,000 to the Trustees of the Philadelphia Museums, to assist in the 'National Exposition for the Encouragement of the Export Trade,' which is to be held the coming fall under the joint auspices of the Philadelphia Commercial Museums and the Franklin Institute, the Board adopted the following resolution:

> "'*Resolved*, That the Committee on Exhibitions be hereby authorized to frame a resolution on behalf of this Board, urging the adoption by the Legislature of the Commonwealth of Pennsylvania, of the Act, making the appropriation of $200,000 above referred to, and present the same to the meeting of the Franklin Institute, with the recommendation of the Board that it be adopted.'

"The Committee on Exhibitions, in accordance with the Board's instructions, has framed the attached preamble and resolution, which is herewith offered for adoption upon the Board's recommendation, as above stated:

> "'To the Honorable Senate and House of Representatives of the Commonwealth of Pennsylvania, assembled at Harrisburg, greeting.
> "'WHEREAS, A bill has been introduced before your Honorable bodies, entitled "An Act Making an Appropriation to the Trustees of the Philadelphia Museums to assist in the National Exposition for the

Encouragement of Export Trade," and asking for an appropriation of the sum of two hundred thousand dollars, therefor; and,

"'WHEREAS, The Franklin Institute of the State of Pennsylvania is associated with the Philadelphia Museums in holding the said National Exposition jointly, the Franklin Institute at its stated meeting held February 15, 1899, adopted, by a unanimous vote, the following resolution:

"'*Resolved*, That the Franklin Institute hereby extends its approval to the aforesaid bill, and urges its prompt and favorable consideration by the members of the Senate and House of Representatives of the Commonwealth of Pennsylvania.'"

Prof. F. L. Garrison, on behalf of the Committee on Exhibitions, gave a summarized statement of the progress made in arranging the preliminaries for the forthcoming exhibition.

Prof. Arthur J. Rowland, Drexel Institute, Philadelphia, made a brief communication on "The Photometry of Incandescent Lamps," describing a special plan of using a photometer for directly determining their candle-power. He illustrated his remarks by a portable photome er, made by the Newark Ornamental Sign and Iron Works, of Newark, N. J. This is a Bunsen photometer, or one in which a measurement of candle-power is effected by moving a paper with a grease spot on it, backward and forward along a line joining two lights to be compared, until the grease spot disappears. The candle-power of one light being known, a measurement of distance to the paper from each of the lights, gives the necessary data for computing the candle-power of the other one.

The features of the photometer shown, were a scale reading directly in candle-power, an incandescent electric lamp is a known standard, and an oil lamp as a sort of secondary or intermediate standard.

In operating the device, the incandescent standard is set up in position where the lamps whose candle-power is to be determined are afterward put, and the flame of the oil lamp adjusted to known candle-power at the other end of the photometer bar. The standard is then removed and other lamps of unknown candle-power substituted and measured. By using the oil lamp in this fashion, nearly all the common difficult and tedious processes of photometry are avoided, only one voltmeter is required, and only one adjustment of the electromotive force given the lamp.

Professor Rowland explained how, from his own experience with the instrument, an accuracy of determination of candle-power to within $\frac{3}{10}$ of a candle-power in 16 is readily attained in a room not especially darkened for the purpose. That is, a single determination will not be more than $\frac{3}{10}$ of a candle-power above or below the true value. This is quite good for a commercial photometer.

The subject was referred to the Committee on Science and the Arts for investigation and report.

Mr. Louis Edward Levy described and exhibited in operation the "Acid-Blast Process for the Etching of Photo-Chemical Engravings," a process and apparatus of his invention.

It consists essentially in the application of a spray of finely atomized etching liquid instead of the immersion bath at present in use, the spray being driven against the plate by a powerful blast of air from an air compressor. The air is forced through a large number of aspirators which

are fixed at the bottom of a shallow tank containing the etching liquid and enclosed in a case to confine the acid vapor. The inlets of the aspirators are submerged in the etching liquid, while the outlets protrude above its level, and these are so arranged that a homogeneous cloud of acid vapor is forced by the air blast against the plate at a right angle to the surface. The plate is fixed on a carrier which slides into a movable frame within the etching box, and is held in a horizontal position with its face downward over the aspirators. The movable frame is connected with an eccentric carried by the driving shaft of the air compressor, and the plate thus receives a slight reciprocal motion in a horizontal plane. This gives a rocking motion to the drops which form in hanging globules on the inverted face of the plate, and which, being held against the plate by the air current, are naturally largest in the wider and deeper depressions of the etching. As the fresh acid particles composing the spray are driven by the blast to the back of these hanging drops and into contact with the metal, the surplus of the drops, carrying the spent acid, falls back into the receptacle below.

Under the impulse of the blast the etching proceeds very rapidly. The heat evolved by the rapid chemical decomposition of the metal is absorbed by the expansion of the compressed air as it escapes into the etching compartment, and this results in keeping down the temperature of the plate and the etching liquid to a normal degree. The fumes developed in the chemical process are carried out of the etching case with the escaping air current through a ventilating pipe to the outer air.

As explained by Mr. Levy, the normal degree of chemical affinity in the minute globules of acid carried by the blast is enhanced by the force of their impact on the metal with which they are intended to combine. This results in each globule of acid becoming saturated with the metallic base instantly on contact with the latter, thus losing its power of further dissolving the metal, and consequently the possibility of etching sideways under the reliefs of the design. As each succeeding globule of acid impinges on the metal in the direction in which the etching is required to proceed, the process can be continued to a depth beyond which the finer and closer lines of the design would become too frail to bear the strain of printing, and at that point the etching is stopped and the finer lines are protected by powdering in the usual way, after which the etching can be carried to the requisite depth.

Attached to the etching box is a washing compartment, into which the plate carrier is slid when the etching liquid is to be washed away from the plate. By an arrangement of three-way cocks connected by a lever, these cocks are opened to permit the air current to drive water from a reservoir up against the face of the plate through perforated pipes at the bottom of the washing compartment.

The blast process as exhibited before the Institute affords a considerable saving of time as compared with the old method, which was also demonstrated by Mr. Levy, and has furthermore the advantage of protecting the etcher against the deleterious effects of the acid fumes.

The paper and demonstration called forth considerable discussion. The subject was referred to the Committee on Science and the Arts.

The Secretary presented a brief report, and the meeting adjourned.

WM. H. WAHL, *Secretary.*